11-1-45.

Vol. XIV, Part I February, 1944

THE INDIAN JOURNAL OF AGRICULTURAL SCIENCE

IMPERIAL INSTITUTE LIBRARY
23 FEB 1945
As. 60 B
SEPARATE

Issued under the authority

of

The Imperial Council of Agricultural Research

Annual subscription
Rs. 15 or 23s. 6d.

Price per part
Rs. 3 or 5s.

PUBLISHED BY THE MANAGER OF PUBLICATIONS, DELHI
PRINTED BY THE MANAGER, GOVERNMENT OF INDIA PRESS, NEW DELHI
1944

ICAR. 5. XIV 1.
600.

CONTENTS

VOL. XIV, PART I

(February 1944)

The Editorial Committee of the Imperial Council of Agricultural Research, India, takes no responsibility for the opinions expressed in this Journal

		PAGE
Original articles—		
PROBLEMS OF SUGARCANE PHYSIOLOGY IN THE DECCAN CANAL TRACT, VI. MINERAL NUTRITION : (B) NITROGEN (WITH THREE TEXT-FIGURES)	*R. D. Rege and S. K. Sannabhadti*	1
STUDIES IN THE PERIODIC PARTIAL FAILURES OF THE PUNJAB-AMERICAN COTTONS IN THE PUNJAB, X. THE INTERRELATION OF SOWING DATE, NITROGEN, WATER-SUPPLY AND SPACING ON GROWTH AND YIELD OF 4F COTTON	*R. H. Dastur and Mukhtar Singh*	18
CYTOLOGICAL INVESTIGATIONS ON AUTO- AND ALLO-TETRAPLOID ASIATIC COTTONS (WITH TWENTY-THREE TEXT-FIGURES)	*N. K. Iyenger*	30
STUDIES ON THE ROOT-ROT OF COTTON IN SIND, I . .	*N. Prasad*	40
FURTHER STUDIES ON THE STEM-ROT DISEASE OF RICE CAUSED BY *Sclerotium oryzae* CATT. IN THE PUNJAB	*C. S. Paracer and J. C. Luthra*	44
SOME RARE AND NEW SMUTS FROM INDIA (WITH TWO TEXT-FIGURES)	*B. B. Mundkur*	49
FURTHER NOTE ON THE BIONOMICS OF *Bemisia Gossypiperda* M. & L., THE WHITE-FLY OF COTTON IN THE PUNJAB (WITH FOUR TEXT-FIGURES)	*K. N. Trehan*	53
STUDIES IN SOIL DISPERSION, I. DISPERSION OF SOILS BY MECHANICAL METHODS	*Amar Nath Puri, Prabhu Dyal and Balwant Rai*	64
A STUDY OF THE FERTILIZING VALUE OF THE SOILS CARRIED IN SUSPENSION BY THE RIVERS OF THE PUNJAB	*R. C. Hoon and C. L. Dhawan*	69
STUDIES ON BASE-EXCHANGE, I. COMPARISON OF BASE-EXCHANGE CAPACITIES AND DEGREE OF SATURATION OF SOME INDIAN SOILS OBTAINED BY DIFFERENT METHODS	*S. K. Mukherjee and S. K. Nandi*	74
A STATISTICAL STUDY OF FLOWER PRODUCTION IN COTTON (WITH FOUR TEXT-FIGURES)	*D. N. Nanda, M. Afzal and V. G. Panse*	78
STUDIES IN THE PRESERVATION OF FRUIT JUICES, III. PREPARATION AND PRESERVATION OF TOMATO JUICE	*Lal Singh and Girdhari Lal*	89
CITRUS ROOTSTOCK TRIALS IN THE PUNJAB, II. THE INFLUENCE OF DIFFERENT ROOTSTOCKS ON THE VIGOUR OF BLOOD-RED ORANGE (WITH PLATE I AND ONE TEXT-FIGURE)	*Lal Singh and Sham Singh*	95
Plant Quarantine Notification		100

ORIGINAL ARTICLES

PROBLEMS OF SUGARCANE PHYSIOLOGY IN THE DECCAN CANAL TRACT

VI. MINERAL NUTRITION: (B) NITROGEN

By R. D. Rege, B.A., M.Sc. (Bom.), Ph.D. (Lond.), A.I.I.Sc., Crop Physiologist, Sugarcane Research Scheme for Deccan*, Padegaon and S. K. Sannabhadti, B. Ag. (Bom.), Graduate Assistant

(Received for publication on 18 October 1943)

(With three text-figures)

Part IV of this paper [Rege and Sannabhadti, 1943], deals with the response of the sugarcane plant to phosphatic manuring which is found to depend upon the initial phosphatic status of the soil. It has been further explained that although certain soil types may show a deficiency of this element at start, necessitating its application, it is soon set right after growing a few sugarcane crops owing to the gradual accumulation of phosphates in the soil from oil cakes which are generally applied as a nitrogenous fertilizer to cane. The total uptake of phosphate by the plant is very low as compared to that of either nitrogen or potash and as the phosphate is scarcely leached down by irrigation all its continuous application is considered unnecessary. On the other hand, in the case of nitrogenous manuring, the general experience is that the crop invariably responds to this manuring quite markedly, independent of the initial nitrogen status of the soil. Consequently the cultivation of sugarcane involves normally a large expenditure on nitrogenous manures alone, doses from 400 to 600 lb. of nitrogen being not uncommon. It is estimated that under normal conditions about 45 per cent of the total cost of cane cultivation is incurred on nitrogenous manures alone. The question of evolving a method of proper manuring was therefore of the utmost importance and with the object of investigating this and other related problems, the Bombay Department of Agriculture established in 1893, an experimental farm at Maniri, at which, after much field experimentation, was evolved the well-known Standard Maniri Method of cane cultivation [Anonymous 1929]. This method recommended sunn green manuring, and a top dressing of 150 lb. N in equal proportions of sulphate of ammonia and oilcakes to be applied in three equal doses—the first in the form of sulphate of ammonia alone at three weeks after planting, the second at eight weeks after planting in a mixture of sulphate of ammonia and oilcakes on equal basis, and the third in the form of cake alone at earthing up time.

This recommendation of total nitrogenous dose was mainly based on economic considerations and was thus found to be of limited applicability. Further the newly introduced high-yielding varieties of sugarcane demanded higher manuring. It was, therefore, realized that in order to evolve a sound system of manuring a thorough investigation was required of (1) the precise quantities of mineral elements absorbed by a normally developed plant, (2) the optimum ratio of these elements beyond which an excess or deficiency of any one element would produce a disturbance in the metabolism of the plant, and (3) the ultimate fate of the fertilizers applied to the plant. This research has been in progress for January-planted cane under the Sugarcane Research Scheme since its inception in 1932 and the work on nitrogen nutriment carried out during the first four years is dealt with in these pages.

Outline of the scheme

All the detailed investigation on the nitrogen nutriment of cane described in these pages has been conducted in soil type B from among the eight soil types in which the soils of the Deccan Canal tract are classified by Basu and Sirur [1938]. This type possesses a dark grey surface soil with an admixture of brown colour and a preamble subsoil which is coloured reddish brown. It is well supplied with calcium carbonate which varies from 9 to 12 per cent, while the nitrogen content is low, being round about 0·045 per cent. The total phosphate is about 0·1 per cent. Field experiments carried out during the first few years showed a distinctly favourable effect of phosphatic manuring and as a result in 1936-37 a dose of 100 lb. P_2O_5 in the form of double superphosphate was given as a basal dressing to all the treatments. The nitrogenous treatments varied from 75 lb. to 600

* This scheme is partly subsidized by the Imperial Council of Agricultural Research

lb. N in graduated doses. It was felt that only through such wide range of treatments would the metabolic effects of nitrogen on cane plants be clearly brought out.

Owing to limitations of space for field experiments and the staff for the analytical work, all the variations in doses could not be tried simultaneously. During the first two years, doses up to 300 lb. N in the variation of 75, 150 and 300 were studied and later on the number of treatments were augmented to five by including higher doses and dropping some lower ones. During all these four years, two varieties—Pundia and POJ 2878—were studied, the former being non-flowering, late maturing and shallow-rooted and the latter flowering, early maturing and deep-rooted. During the first two years, the nitrogenous quantities were applied, in equal proportions of sulphate of ammonia and oilcakes divided in three doses as recommended in the Standard Manjri Method. Finding, however, some deleterious effect of this method of application in higher nitrogenous top dressings, the proportion of sulphate of ammonia to oilcakes was changed to one-third and two-thirds and the distribution to four doses in later years. The methods of cultivation, planting, irrigation, etc., were kept the same as recommended in the Manjri Standard Method. There were duplicate plots per treatment, the plot side being 28 ft. × 38 ft. with cane rows four feet apart. From September onwards, lodging of cane was observed in higher nitrogenous treatments and was specially severe in Pundia.

Detailed observations were taken on the developmental behaviour of the crop and some physiological characteristics. In addition to periodical botanical observations on the standing cane for the determination of the rate of growth, plants were also periodically cut on an area basis for yield per acre and also uptake of nutrients, the normal constituents determined being N, P, K and Ca. Owing to limitations of space, it is not proposed to discuss always the data of each year separately. Wherever possible, it will be dealt with in a general way for all the graduated doses under study after making due allowance for the seasonal fluctuations on the basis of the treatment of 300 lb. N which was common to all the four seasons. The methods used in field observations and analytical work were the same as described in Part IV of this paper.

Experimental

A. Developmental studies

Germination. It has been shown by Rege and Wagle [1939] that although the reserve material in the seed piece exercises an important control on the process of germination, application of sulphate of ammonia at planting is beneficial as it accelerates the germinative capacity conducive to higher germination. The bulky manures as sunn green manuring or compost are not of any use in this respect. This will be evident from Table I in which the results of two separate experiments are illustrated.

During the first season the variety was POJ 2878 and in the second Co. 419. In the case of top dressings of 300 lb. N one-tenth of the dose, i.e. 30 lb. N was applied at planting time in the form of sulphate of ammonia alone. In our experimental work on nitrogen nutriment this procedure was adopted in all the treatments varying from 75 to 600 lb. N. It was observed that only in the case of 75 lb. N in which the planting dose was 7·5 lb. N the germination was low, the figure in POJ 2878 at eight weeks count being 80·6±3·2 as against 88·7 ± 3·4 in the case of 150 lb. N. On the other hand, all the higher treatments have equalled this

Table I

Periodic data of germination

(Per cent of the total number of buds planted)

Treatment per acre	1938-39		1939-40	
	3 weeks	8 weeks	3 weeks	8 weeks
(1) Sunn green manuring	36·3±1·3	77·5±0·99	..	..
(2) Sunn green manuring+300 lb. N.	42·1±0·76	82·3±4·9	..	..
(3) No manure	..	..	22·7±5·20	56·7±4·00
(4) Compost 20,000 lb.	..	..	21·7±4·07	59·5±6·30
(5) Compost+300 lb. N..	..	..	36·8±3·96	64·9±3·66
(6) 300 lb. N.	..	..	30·7±3·66	66·7±3·96

treatment of 150 lb. N. The minimum dose required for securing the optimum germination is thus 15 lb N as sulphate of ammonia and increasing this quantity even up to 60 lb. N has been found to be of no further advantage.

Tillering and horer counts. Besides periodical counting of the total population, the method of labelling all tillers emerging from a germinated bud was adopted in the case of ten randomly selected plants per treatment in order to get a correct idea about the influence of treatments on the tillering capacity and the ultimate fate of the tillers so formed. As the latter method has brought this out more clearly than the former, these data are only presented according to the month of the appearance of tillers and their ultimate success (Tables II and III). The figures are given for the first two seasons only as in later seasons the tillering performance has been quite similar in all the treatments owing to the dropping of the lowest nitrogenous dose of 75 lb. N from further investigation.

TABLE II

Tillering performance 1934-35

Treatment	April		May		June		July		Total per cent success	Ratio of tillers to mother cane
	Per cent of total tillers formed	Per cent tillers successful	Per cent of total tillers formed	Per cent tillers successful	Per cent of total tillers formed	Per cent tillers successful	Per cent of total tillers formed	Per cent tillers successful		
POJ 2878										
75 lb. N	39·1	10·8	50·0	8·7	10·9	4·3	..	..	23·8	4·6
150 lb. N	55·4	28·1	38·6	3·5	7·0	..	..	..	31·6	5·7
300 lb. N	50·0	25·9	37·0	9·3	13·0	1·8	..	..	37·0	5·4
Pundia										
75 lb. N	40·3	10·5	35·1	8·7	24·6	5·3	..	..	24·7	5·7
150 lb. N	34·9	14·3	33·3	6·4	30·2	4·8	1·6	..	25·5	6·3
300 lb. N	21·4	7·1	30·4	5·4	37·5	6·3	10·7	1·8	20·6	12·2

TABLE III

Tillering performance 1935-36

Treatment	April		May		June		July		Total per cent success	Ratio of total tillers to mother cane
	Per cent tillers formed	Per cent tillers successful	Per cent tillers formed	Per cent tillers successful	Per cent tillers formed	Per cent tillers successful	Per cent tillers formed	Per cent tillers successful		
POJ 2878—										
75 lb. N	48·8	14·0	48·8	0·0	..	..	2·3	0·0	14·0	4·3
150 lb. N	66·0	21·2	17·0	4·3	2·1	0·0	14·9	2·1	27·7	4·7
300 lb. N	42·9	12·5	48·2	10·7	..	..	8·9	0·0	23·2	5·6
450 lb. N	48·0	24·0	30·0	10·0	14·0	0·0	8·0	0·0	34·0	5·0
600 lb. N	40·0	16·9	41·5	12·3	3·1	0·0	15·4	0·0	29·2	6·5
Pundia—										
75 lb. N	41·2	17·6	47·1	11·8	5·9	0·0	5·9	0·0	29·4	5·1
150 lb. N	38·6	14·0	56·1	10·5	..	..	5·3	0·0	24·6	5·7
300 lb. N	36·8	36·8	54·4	1·8	..	..	8·8	1·8	40·4	5·7
450 lb. N	41·6	10·3	41·4	12·1	8·6	0·0	3·7	0·0	24·1	5·8
600 lb .N	26·3	21·1	61·4	10·1	5·3	3·5	7·0	0·0	35·1	5·7

In general it may be stated that early formed tillers, i.e. those formed in April and May, come out more successful than later ones. Coming to the data of individual seasons, the data of the first season (Table II) has brought out clearly the varietal characteristics. In the case of Pundia there is an increased tillering with increased top dressings which in the treatment of 300 lb. N reached such an abnormal figure as 12·2 tillers to one of mother plant. The periodical harvest data which will be discussed under (c) have further shown greater production of leaf than cane in this treatment and it was mainly the smothering of a large number

of tillers during the process of earthing which was conducive to the normal performance of growth later. This abnormal behaviour of the plant at the tillering phase in this high nitrogenous series appears to be due to the high concentration of nitrogen in the soil solution as a result of the adoption of the Standard Manjri Method in the distribution of top dressings. According to this method of distribution the crop received 200 lb. N within two months from planting, out of which 150 lb. N was in the form of sulphate of ammonia alone. This has affected adversely Pundia and not POJ 2878 which, it seems, can withstand higher concentration of soil solution. This is further confirmed by the data of the next season (Table III) in which the proportion of sulphate of ammonia to cake as well as the distribution of the total dose were modified by reducing the quantity of sulphate of ammonia to one-third from one-half of the total dose, and increasing the distribution to four times instead of three. With this modification, even in the case of 600 lb. N, in which the maximum quantity received within two months as sulphate of ammonia was 100 lb. N. only, the abnormal stimulus to tillering is not visible. The low availability of nitrogen reduces the tillering capacity, the limit of nitrogenous top-dressings being 150 lb. N in this respect. On the other hand it has already been shown [Rege and Sannabhadti, 1943] that a basal dose of 100 lb. P_2O_5 accelerates the tillering capacity even in the absence of nitrogenous top dressing and it is only at the growth phase that deficiency of nitrogen comes into prominence causing death of most of the tillers. It is thus apparent that so far as the tillering phase is concerned, phosphates are more important and can even obliterate the adverse effect of the deficiency of nitrogen.

No definite conclusion could be drawn from the data of borer infestation owing to a great deal of fluctuation in the figures obtained for the different treatments. The only outstanding factor which has emerged from these data is that Pundia is more susceptible to borer attack than POJ 2878.

Growth. The profuse tillering in Pundia during the first season in the case of 300 lb. N had not only adversely affected the total production in mid-June by reducing it by 48 and 20 per cent as compared to the lower treatments of 75 and 150 lb. N respectively but had further shown an abnormal rise in the ratio of the weights of the functioning leaves to stem, the figure being 33·6 as against 6 in the lower treatments. In the case of POJ 2878 no such abnormality could be traced, the ratios for both 150 and 300 lb. N being practically similar and only slightly higher than that for 75 lb. N. During the next season also no abnormal differences in the ratios could be observed between the treatments varying from 75 to 600 lb. N in the case of both the varieties. The adoption of the standard method of manuring in such heavy doses has evidently been mainly responsible for the leafy growth, and this is amended by the modification in manuring followed during the next season. In the present case also, the method of using oil cakes for manuring just before earthing followed by this operation of earthing up has been beneficial in correcting the early adverse effect of manuring. Earthing up has not only smothered many of the tillers but has checked further tillering, thus reducing the ratio of leaves to stem practically to the same figures obtained in the lower treatments. Further, manuring with oilcake has helped to keep down the concentration of soil solution to the beneficial limit, owing to its slow availability and as a result, from August onwards, this treatment has put on pace in growth, coming eventually superior to others in the end.

In order to find out the optimum concentration of nitrogen in solution for securing best growth, a sand-culture experiment was conducted with salt solution consisting of three variations of nitrogen on the basis of the one-third dose of the treatments of 150, 300 and 600 lb. N. Sulphate of ammonia was used to supply nitrogen, while other salts as phosphate, potash, etc. were supplied in the form of usual standard chemicals. There was a control treatment consisting of water alone as well-water was used for dilution of the salt cultures. Pots were of Jubbulpore burnt clay and there were four pots for each treatment. The application of culture solutions was started immediately after germination and was continued for three months, at the end of which period the crop was harvested. The data are given in Table IV.

The above data show that for the best growth an optimum concentration of sulphate of ammonia equal to 50 lb. N per acre is essential. No doubt this quantity will be slightly more in the case of soil in order to compensate for its adsorbing power; but concentrations above 100 lb. N are found to be definitely injurious to varieties like Pundia. In the case of POJ 2878, although 50 lb. N has come out the best, the next concentration equal to 100 lb. N (one-third of the treatment of 300 lb. N) has also given significantly better results than control. This variable response of the varieties to the concentration of nutrients seems to be due to

TABLE IV

Sand culture series 1935-36

Treatment and variety	Oven dry weight per pot in gm.		
	Aerial portion	Roots	Total
POJ 2878			
Control . .	16·0	6·3	22·3
150 lb. N . .	93·1	11·6	104·7
300 lb. N . .	64·4	7·6	72·2
600 lb. N . .	40·3	3·8	44·1
Pundia			
Control . .	9·5	3·0	12·5
150 lb. N . .	31·4	5·1	36·5
300 lb. N . .	16·3	2·1	18·4
600 lb. N . .	7·5	1·7	9·2
C. D. between any two treatments .	..	..	22·5

the differential permeability of roots of these varieties. The determination of the osmotic pressure of the sap collected from the roots of these varieties has, in fact, shown it to be 26 per cent higher in the case of POJ 2878 than that in Pundia.

The relative growth rate per stool per day which is calculated according to Fisher's formula [1932] from the monthly production of total dry matter (inclusive of dry, green leaves and stem) is illustrated on a percentage basis in Fig. 1 for the season 1935-36. This season was selected for illustration mainly because both the lowest and the highest treatments under investigation were present and secondly monthly samples beginning from fourth month were

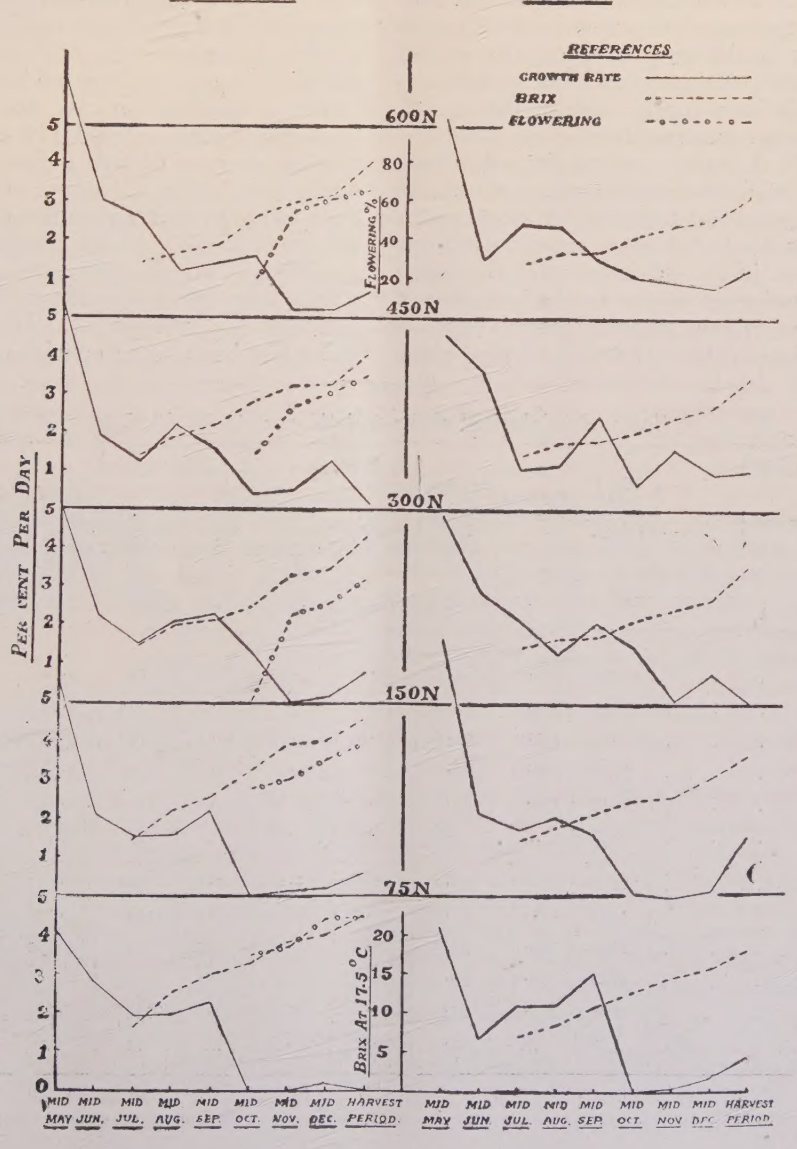

FIG. 1. Relative growth rate (Fisher's Formula)

collected for the determination of growth only during this season. During later years the lowest treatment of 75 lb. N was dropped and further the periods of sampling were reduced to five depending upon the plant phases. The comparison of the data of the relative growth rate has, however, shown trends similar to those illustrated above. There are two peaks in general, the first showing the highest rate. The second peak, which comes by about September, coincides with the grand period of growth if one considers the actual increase in weight irrespective of the previous weight which is the basis of the calculation by this formula. Coming to the treatments, two facts emerge quite clearly. Up to about eight months the relative growth rate is practically similar in all the treatments except in 75 lb. N which has shown a slower rate at start. In the case of lower treatments as 75 and 150 lb. N the growth practically ceased after this period. This cessation of growth occurred a month later in the case of 300 lb. N, while in the higher treatments it was not observed throughout. In the case of the flowering variety (POJ 2878) the continuation of growth seems to be due to the slow rate of flowering in these higher treatments, (see curves for flowering). The spurt in growth in most of the treatments in the end may be due to the inclusion of water shoots of which separate record was not kept at the time. Das [1936] had also come to similar conclusion in his experimental work with three series of low, medium and high nitrogenous manuring. According to him all these series grew at about an equal rate until the ninth month and then the low N series began to lag behind the other two.

The figures for final dry weight (col. 2, Table V) show an upward gradient with increasing doses of nitrogen. They are also a good illustration of the law of diminishing returns as could be evident from the figures of percentage increase given in col. 3, Table V. Although the growth has practically ceased at the same time in 75 and 150 lb. N, its slow rate at start coupled with the low tillering seems to have been responsible for the lower yield in the case of the former treatment.

In Table V also, the data of some of the physiological characteristics have been given. The number of leaves and their measurements are the average of the ten periodic samples. The carbon assimilation is determined by the Ganong's punch method [1908] and the figures are the average of five monthly estimations till September. This procedure of averaging out has been followed firstly because it has enabled us to present the data within limited dimensions and secondly it has smoothened out the periodical fluctuations thus revealing the real differences between the treatments. However, whenever there has been some consistency in the periodic

TABLE V

Some physiological characteristic per stools, 1935-36

Treatment and variety	Final total dry wt. in gm.	Per cent increase	Average No. of functioning leaves	In inches		In square inches		Dry wt. per sq. in. of leaf surface (gm).	Carbon assimilation per cent	Final ratio of total leaves to stem	Final ratio of dry leaves to green leaves
				Average length per leaf (L)	Average breadth per leaf (b)	leaf area ($L \times \frac{1}{2} b$)	Total area per stool				
1	2	3	4	5	6	7	8	9	10	11	12
POJ 2878—											
75 lb. N	853	100·0	16·9	44·1	1·99	43·8	740	0·153	9·4	0·84	3·59
150 lb. N	1162	135·0	18·6	47·8	2·17	51·8	963	0·145	9·2	0·57	1·87
300 lb. N	1386	162·3	20·5	51·0	2·25	57·4	1177	0·142	7·9	0·59	1·19
450 lb. N	1593	186·7	20·6	52·7	2·37	62·5	1288	0·141	8·2	0·48	0·98
600 lb. N	1642	192·5	24·3	49·8	2·33	58·0	1409	0·140	11·3	0·46	0·93
C. D.	337	...	3·2	2·4	0·33	...	...	...	...	...	...
Pundia—											
75 lb. N	1227	100·0	20·4	50·0	1·90	47·5	969	0·135	12·7	0·57	1·41
150 lb. N	1444	117·7	25·9	52·4	1·84	48·2	1248	0·140	12·2	0·44	1·09
300 lb. N	1619	132·0	27·8	53·5	1·95	52·2	1441	0·136	11·3	0·46	0·93
450 lb. N	1749	142·5	28·3	53·7	1·94	52·1	1474	0·132	14·7	0·46	0·75
600 lb. N	1906	155·3	28·1	54·5	1·96	53·4	1501	0·123	15·3	0·50	0·59
C. D.	406	...	3·5	1·48	0·18	...	...	...	...	...	...

fluctuations these have been referred to during the course of the discussion.

The data show that there has been a progressive increase in the number of functioning leaves with increasing applications of nitrogen, the significance being only observed between 75 lb. N and 300 lb. N and above in the case of POJ 2878 and 75 lb. N and all others in Pundia. The leaf area per leaf is also similarly affected. This has been, in fact, the case in practically every periodic sampling. It will be further seen that both the length and breadth of functioning leaves are favourably influenced by the nitrogenous manuring, the optimum figure being about 300 lb. N. This does not agree with the findings of Das [1936], who states that the treatment differences on width are the reverse of those on length, the high N series having the widest leaves. Studies of periodic figures have shown that both blade length and width have increased in all the treatments from month to month up to July, i.e. first six months, and then have remained constant for a period which has varied according to the treatments and varieties. Thus in the case of POJ 2878 this period lasts for about three months, i.e. till September, in the lower treatments of 75 and 150 lb. N while it extends till December in the higher ones. This seems to be due to early start in flowering in the lower treatments. No such variation between treatments is observed in Pundia even till the end in all the treatments, the leaf area per treatment remaining practically constant from July onwards till the end. This shows that the size of the leaf is a function of the age of the plant and is further controlled by the climatic and nutritional conditions. The maximum leaf area occurs at the climatic conditions most suited for the plant growth. Further, as long as the availability of nitrogen continues this maximum size of the leaf continues and with its deficiency it diminishes. The rate of carbon assimilation (col. 10, Table V) which represents the percentage increase in dry weight at 3 p. m. over 8 a.m. does not show any significant variation between the treatments. When one, however, considers, the leaf area, the effect of increased nitrogen on total carbon assimilation is evident. This is in agreement with the findings of Gregory [1926], who working with barley has shown that only the leaf area increases and not the assimilation rate with increased nitrogen.

The figures for dry weight per square inch of the leaf surface distinguish the treatments of 75 and 150 lb. N from the higher ones by their greater weights. According to Russell [1937], greater quantities of nitrates lead to the development of large dark green leaves which are often crinkled and soft because of the thinning of the walls or of changes in tissues. It has already been stated that higher manuring had led to an increase in leaf area mainly up to a limit of 300 lb. N. There was also a development of green colour which was more evident in the case of Pundia than in POJ 2878, but it was not combined with the crinkled appearance even in the highest manurial dose. In the absence of anatomical studies, however, nothing can be stated as regards the differences in the cell structure.

The ratio of total leaves to stem (col. 11, Table V) reveal a greater production of stem than leaves in the end with increasing nitrogen in the case of POJ 2878 and practically a constant figure for Pundia in treatments above 75 lb. N. This increased production of stem would be of commercial advantage as the stems form the raw material for the production of *gur* or sugar. A similar instance has been given by Russell [1937] for mangolds in which increased roots are obtained by increased nitrogen while swedes sugarbeet and potato crops produce more leaves. In the case of sugarcane one must, however, remember the operation of earthing up which smothers the excessively formed tillers and it would be very interesting to see whether the same results would have been obtained in case this operation would have been dropped. The proportion of dry leaves to green leaves support the well-established fact of the deferment of the yellowing and death of the leaves with increased nitrogen.

In order to find out how far the first order stalks or mother canes and tillers formed during different months contribute to the total cane weights per stool in the end, individual stalks from ten stools labelled for tillering were separately weighed and their percentage contribution calculated. Owing to borer attack the number of stools under observation are not sufficient to yield conclusive evidence above the effect of the various treatments. The figures have, however, shown that the contribution from the first order stalks varies between 30 to 40 per cent in the case of POJ 2878 and 15 to 20 per cent in the case of Pundia except in some lower nitrogenous doses. The rest of the weight is practically made up by tillers formed in April and May. It has been further observed from the weight of the individual canes that generally the growth of the mother cane is poorer than that of April-formed tillers and even tillers formed in May have shown the same trend in the

case of higher nitrogen in Pundia. These tillers have also attained practically the same brix as the mother canes at harvest and as such their contribution to the tonnages of both cane and sugar per acre would be considerable.

The periodical strip sampling is utilized for the estimation of tonnage as well as mineral requirement per acre, which is of great practical importance for the evolution of a manuring system. For this purpose, sampling of 3 ft. length strips is found to be more reliable than the usual method of stool sampling, mainly because there is a very large reduction in the number of stools per acre with the advance in crop growth owing to the mortality of stools either by borer or other extraneous causes, which could not be accurately determined, except without disturbing the soil and roots at the base of the plant, once the full tillering is attained and the crop is earthed up. Thus it was found that on an average in POJ 2878 there were 19,965 stools per acre at four months from planting, 13,798 at eight months and 12,342 at twelve months. The calculation of cane tonnages or their mineral requirement on the first count of stools at four months only, when counting could be done without disturbing the plant, would thus give abnormal results. During strip sampling, however, the number of stools per strip were carefully counted, the number of strips for each sampling time being eight during the early stages of crop growth and five later. The cane tonnages at harvest only are represented in Tables VII and VIII for 1935-36 and 1936-37 with the data of maturity as well. During the latter season a basal dose of phosphate was applied and its effect is visible specially in lower nitrogenous series. In general there is an increase in tonnages with increased doses even up to 600 lb. N, specially in POJ 2878, the rise being steeper up to 300 lb. N than in higher treatments. Large-scale replicated trials conducted for three years with varying doses up to 375 lb. N have, however, shown no significant increase in cane tonnages in 375 lb. N over 300 lb. N. The data (average of three years) are given in Table VI. Instead of Pundia the variety under trial was Co. 419, it also being a late-maturing one.

Root system. The effect of increased dose of nitrogen on the root system has already been discussed in detail in a previous paper by Rege and Wagle [1941]. In general it may be stated that there has been a reduction in the root system with increasing nitrogen, thus exhibiting an inverse relationship with the stool weights. The distribution of roots in the various soil depths have shown more intensity in the lower depths in higher manuring. It is suggested that this may be meant to support the high weight of the cane with a view to preventing its lodging.

Maturity. This is judged by monthly estimation of Brix from mid-September onwards. These data are illustrated in Fig. 1 for the season 1935-36. Detailed analyses for sucrose and glucose are carried out for a few periods and are given in Table VII. It would be seen that the effect of treatments is more clearly brought out by these detailed analyses than by the figures of Brix alone. Even in cases where the figures for Brix are similar (col. 8, Table VII under Pundia) for all the treatments, there has been a definite fall in sucrose in treatments of 300 lb. N and above. The low figure for sucrose at harvest time in the treatment of 75 lb. N in the case of POJ 2878 seems to be due to its remaining in the field long after its attainment of maximum maturity. The other treatments have

TABLE VI

Harvest data (1939-1942)

(Average of six replicates per season)

Treatments	Cane (Tons per acre)	Sucrose per cent	C.C.S. per acre	Period of harvest
POJ 2878				
225 lb. N	39·55	16·28	5·59	First week of February
300 lb. N	43·51	15·97	5·91	
375 lb. N	46·99	15·34	6·41	
CO. 419				
225 lb. N	54·84	14·76	6·57	Fourth week of February
300 lb. N	59·31	13·56	6·33	
375 lb. N	62·12	12·93	6·23	
C. D.	4·45	..	0·57	

shown a tendency towards rise in sucrose and it was, therefore, felt that delaying of harvest might still increase the sucrose content further. In order to test this, the crop was continued in the field during the following season with periodical sampling till end of April (Table VIII). In POJ 2878, 150 lb. N attained the maximum maturity by the end of February while the rest

TABLE VII

Periodical maturity tests

(Percentage on cane juice 1935-36)

Treatment	Mid-September			Mid-November			Harvest time					
	Brix at 17·5°C	Sucrose per cent	Glucose per cent	Brix at 17·5°C	Sucrose per cent	Glucose per cent.	Brix at 17·5 °C	Sucrose per cent	Glucose per cent	Yield tons per acre	C. C. S. tons per acre	Date of harvest
1	2	3	4	5	6	7	8	9	10	11	12	13
POJ 2878—												
75 lb. N . . .	14·7	10·4	1·96	19·0	17·7	0·62	20·9	17·5	0·73	28·1	3·27	31-1-36
150 lb. N . . .	12·9	8·6	2·67	19·9	17·6	0·78	21·8	18·9	0·49	37·8	4·97	Do.
300 lb. N . . .	10·4	5·2	3·63	16·6	13·1	2·10	21·9	18·4	0·87	45·4	5·62	1-2-36
450 lb. N . . .	10·7	5·0	4·12	15·9	12·3	2·23	20·7	16·6	0·92	45·8	4·96	Do.
600 lb. N . . .	9·4	4·1	4·25	15·0	10·7	2·23	20·2	16·4	1·02	49·3	5·34	Do.
Pundia—												
75 lb. N . . .	10·9	5·6	4·00	14·9	11·5	2·10	18·7	16·0	1·21	34·0	3·80	24-2-36
150 lb. N . . .	10·7	5·8	4·76	13·0	9·2	3·10	18·9	16·4	1·14	38·0	4·42	Do.
300 lb. N . . .	8·4	2·6	4·78	11·9	7·8	3·25	18·4	14·6	2·04	50·8	4·86	4-3-36
450 lb. N . . .	8·9	2·9	7·29	12·1	7·4	7·41	18·8	14·5	2·50	50·1	4·77	Do.
600 lb. N . . .	8·7	2·5	7·43	12·0	7·3	7·41	18·5	13·1	3·48	52·1	4·17	Do.

Note. C. C. S. is calculated according to the Srivastava's formula

$$\frac{3P}{2}\left(1-\frac{10+F}{100}\right)-\frac{B}{2}\left(1-\frac{6+F}{100}\right)$$

TABLE VIII

Periodical maturity tests

(Percentage on cane juice 1936-37)

S. No.	Treatment	Cane yields (tons per acre)	26 Feb. 1937		29 March 1937			17 April 1937		27 April 1937			C. C. S. tons per acre
			Brix at 17·5°C.	Sucrose per cent	Extraction per cent	Birx at 17·5°C	Sucrose per cent	Brix at 17·5°C	Sucrose per cent	Extraction per cent	Brix at 17·5°C	Sucrose per cent	
	1	2	3	4	5	6	7	8	9	10	11	12	13
	POJ 2878												
1	150 lb. N . .	36·0	23·2	21·4	36·3	22·3	20·7	21·8	19·8	26·1	19·6	17·8	5·45
2	225 lb. N . .	42·4	21·9	19·7	40·5	22·0	20·0	20·3	18·5	24·2	19·6	17·8	5·97
3	300 lb. N . .	44·1	20·9	17·7	40·6	22·6	20·5	20·5	18·5	22·1	19·1	17·3	6·41
4	450 lb. N . .	45·5	20·6	17·9	43·4	22·2	19·9	19·8	17·8	25·2	19·3	17·4	6·39
5	600 lb. N . .	49·4	19·7	17·0	47·0	21·4	18·9	17·4	15·0	28·1	17·0	14·6	6·57
	Pundia—												
6	150 lb. N . .	42·9	19·7	16·5	53·1	19·1	16·8	17·8	15·0	33·8	16·7	13·8	4·88
7	225 lb. N . .	45·4	18·7	16·2	55·0	18·5	16·5	18·9	15·9	39·0	19·8	15·7	5·01
8	300 lb. N . .	55·7	17·4	14·3	51·1	17·5	14·9	18·4	14·8	39·6	19·3	15·3	5·58
9	450 lb. N . .	53·2	16·5	12·7	55·2	17·1	12·3	17·8	14·6	38·8	16·2	14·0	5·36
10	600 lb. N .	54·8	17·2	13·0	57·1	16·8	12·6	14·3	12·4	41·2	16·5	12·9	4·72

showed rise till the end of March followed by a fall in April with the rise in temperature. Further the highest figure of sucrose is observed in 150 lb. N closely followed by treatments of 225, 300 and 450 lb. N, while the last one has shown a drop by about 1 per cent. In the case of Pundia, the highest figure for sucrose is observed in samples taken on 29 March in the treatments of 150 and 225 lb. N only. The other treatments showed some rise in later samplings, but even till last the figure did not come up to this maximum one except in the case of 300 lb. N. Besides in these later samplings, there is an appreciable fall in extraction (cols. 5 and 10, Table VIII) due to increase in pithy fibre and formation of cavity in the centre of the stem, which are more pronounced in the case of POJ 2878 than in Pundia. These findings are of great economic importance in that, although increased quantities of nitrogen may yield some increase in cane tonnages, they bring about delay in sucrose formation, which owing to short period of favourable climate, may not thus be able to give equally higher yields of sugar—an important commercial product.

The figures for commercial cane sugar given in the last column in both the tables are calculated on the basis of analytical results at harvest time for 1935-36 and on maximum maturity for the next season. The comparison of the two years' data clearly shows the advantage of harvesting at the time of maximum maturity as even in the case of the same tonnages it has given from 0·5 to 0·8 tons sugar more per acre during the latter year. These figures further give a clear idea of the limits of nitrogenous applications. In this respect varieties differ in their response according to their inherent characteristic of sucrose development. Thus, while in the case of early-maturing variety as POJ 2878 one can go up to 600 lb. N, this last dose of nitrogen is definitely deleterious in the case of the late-maturing variety as Pundia. Similar will be the result with Co. 419 which is at present a leading cane in the Deccan Canal Tract as it also is a late-maturing variety. On economic considerations 300 lb. N appears to be the optimum dose for this planting in the case of all the varieties.

B. Mineral nutrition

For these investigations the plant material from periodical samplings for the growth studies was used. During the maturity period a few important constituents were also determined in the cane juice and *gul*. The details of the methods are given in our previous communication [Rege *et al.* 1943]. The availability of nutrients was estimated by the periodical analysis of the soil as well as exudates obtained from cane stools. In the former case only availability of nitrogen could be tested, while in the latter N, P, K and Ca were estimated by the colorimetric method of Steenkamp [1934].

Water content. The water contents of green leaves and stems were determined every time the plant sampling was done. During 1935-36, monthly figures are available which are further averaged according to the three plant phases of formative, growth and maturity respectively. In the case of leaves, the water content is calculated both in relation to leaf area and to the dry weight, while the figures for stems are based on dry weight only. All these are given in Table IX. In general, there has been a reduction in the water content of the leaf with the progress of time in both leaves and stems when the figures of the ratio of water to dry weight are considered. Similar ratios of water to leaf area, however, show quite the reverse phenomenon in that a higher water content is observed at the later stages, the grand period stage coming out the highest in this respect. Similar data of later years have confirmed this finding. This contradiction in the figures calculated by these two methods is apparently due to the periodical variation in the dry weight per unit leaf area which is less in the beginning and increases with the advance in age. We have shown in our previous communication on phosphate that such physiological processes as photosynthesis are not at all influenced by the dry weight of the leaf. It is the leaf area which is of importance and in this respect it seems that working out the ratios of water content to leaf area, as recommended by Gregory and Richards [1929], will give a real picture of the influence of the water content on the various physiological processes than the ratios of water content and dry weight.

Coming to the individual treatments, there is practically no difference in the water content of the leaves in the formative stage in both the varieties. During later stages higher succulence is observed in the case of 450 lb. N and above in POJ 2878, while in Pundia the data have shown practically no variation. Similar results are also obtained in the case of stems. There is, however, no clear evidence as obtained by Das [1936] to show that this greater succulence in the higher treatments is of any advantage from the standpoint of growth. This may be due to continuous irrigation which this crop has

received throughout its life cycle, which has been able to maintain the soil moisture at its optimum level for the physiological processes pertaining to growth even in the lower nitrogenous treatments and therefore this higher succulence in the other treatments is not of much use. On the other hand dehydration of stems seems to have a good relation with the sucrose formation, as the treatments with lower nitrogenous manuring, which show higher sucrose content in cane, are characterized by low water content. Among the varieties also POJ 2878, which has shown higher dehydration than Pundia, contains greater sucrose.

Uptake of mineral nutrients. Only four important nutrients—N, P, K, and Ca—are estimated in the different organs of the plant except roots, whose collection free from clay particles in the case of the black cotton soil was found to be extremely difficult. The data thus obtained were calculated in more ways than one, e.g. per 100 gm. of each part of the plant, per 100 gm. of the whole plant, and on the basis of whole plant, stool as well as acre. The trends in the case of the first method of calculation have been practically the same as illustrated in our previous paper [Rege *et al.*, 1943] such as a higher fall in all the constituents in stems than in green leaves with the progress of growth and the migration of nitrogen, phosphate and potash to other parts when the leaves become physiologically inactive and dry, the highest migration being observed in the case of phosphate. Due to the limitations of space these data are not given. Only the data per 100 gm. of whole plant are graphically represented in Fig. 2. These curves for the whole plant practically reflect the total effect of the fluctuations in the different organs. Among the different nutrients nitrogen shows the highest fall followed by phosphates. For instance, taking the starting percentage figures for April as 100, the figure for January has shown about 25 per cent of this nitrogen, 45 per cent of phosphate, 68 per cent of potash, and nearly the same percentage of calcium in 100 gm. of the plant material. In the case of potash, even an increased percentage of uptake continues for a few months after April. It is thus apparent that per unit of nitrogen absorbed there is much more production of dry matter than in the case of other constituents the next in importance being phosphate. Among the varieties, a higher level of uptake of only phosphate is observed in Pundia throughout its life-cycle than in POJ 2878 with practically no difference as regards the uptake in the other constituents.

Coming to the individual treatments, the differentiation in the percentage uptake is only evident in the case of nitrogen specially at later stages of grand period and at the stage of maturity, when the nitrogenous level is much less in lower treatments than 300 lb. N and above. This is in consonance with the performance of the plant in the growth phase discussed above and clearly reveals the influence of nitrogen on this phase. As regards the other constituents the small fluctuations between the treatments do not show any definite trend, the uptake being on the whole practically similar in all the cases. This has affected the ratios of nitrogen to other constituents, which continues to be higher in the higher treatments. This unbalanced nutrition may be the reason of the continued growth and low maturity observed in such higher doses as 450 and 600 lb. N. The application of a basal dose of 100 lb. P_2O_5 as superphosphate during the following season of 1936-37 has also been ineffective in improving these ratios. This has been already shown [Rege *et al.*, 1943] to be due to the increase in the uptake of nitrogen as a result of this phosphatic application. Similar results have been obtained by Dutort and Beaker [1939], who found greater absorption of N by Co. 301 with greater quantity of P_2O_5 in the soil.

From the standpoint of the practical agriculturist the total uptake per acre is of importance and is therefore given for a few periods in Table X. As the optimum uptake varied according to the treatments from October to December, the figures under this heading represent the uptake in different months and not at the harvest time, as all the constituents at this time show a fall. It seems that as the cane attains maturity there is a return of plant food to the soil and harvesting the crop at its maximum maturity, besides giving higher yields of sugar or *gul* will also contribute to the agricultural economy, as less plant food is then removed.

The data clearly prove that cane plants absorb the principal nutrient elements in widely different amounts, potash being taken up to the greatest extent and phosphate the least. The uptake of nitrogen and calcium is intermediate, that of the former being slightly higher than that of the latter. Further the rate at which several nutrients are absorbed varies with the age of the plant but not always in the same degree for each nutrient. This would be clear if one assumed the optimum uptake to be 100 and calculated the uptake at earlier stages on the basis of it. It would be then seen that the

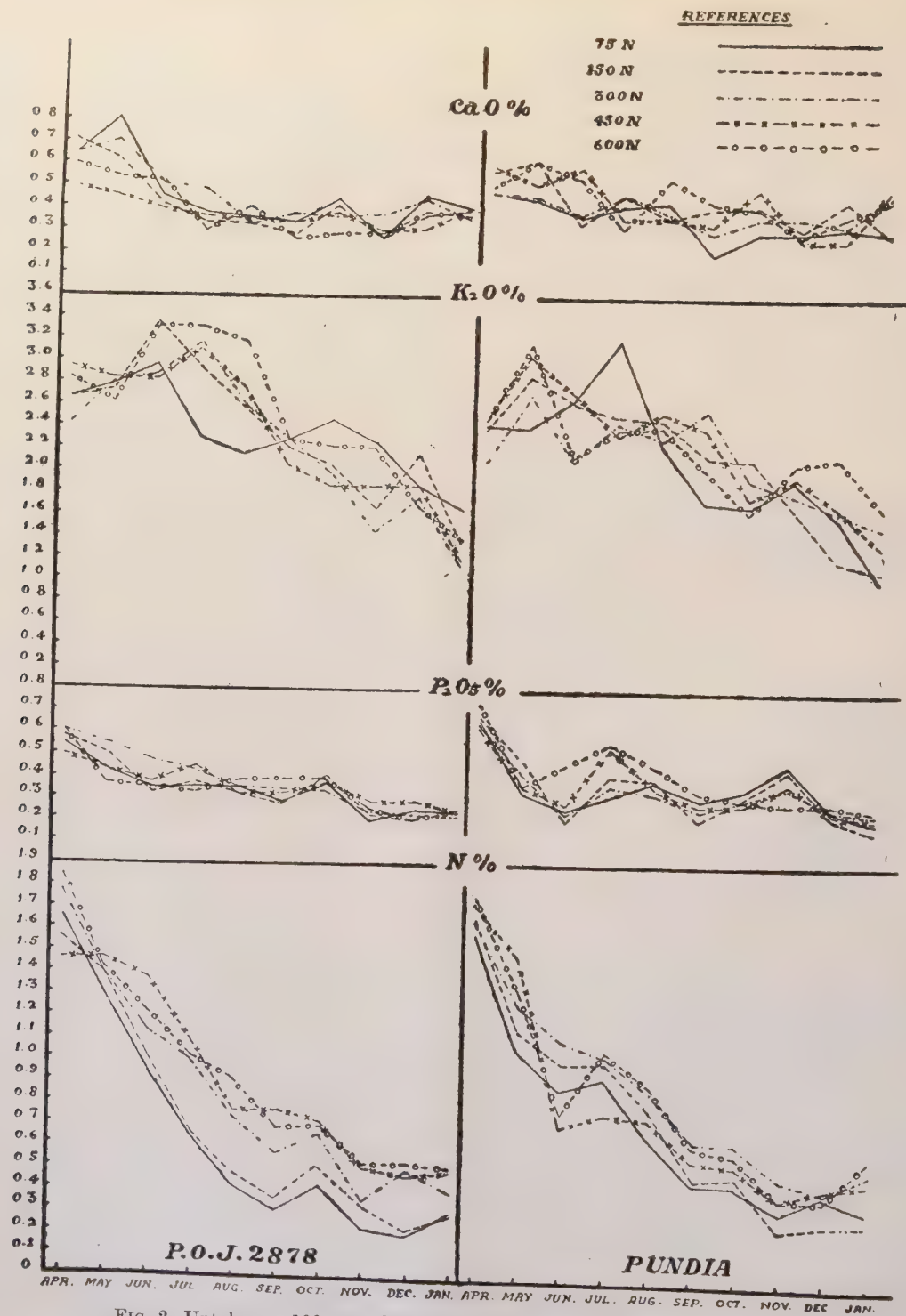

FIG. 2. Uptake per 100 gm. of plant material (Oven dry basis)—1935-36

rate of uptake is highest in the case of nitrogen closely followed by that of potash, while it is the least in the case of phosphate. Thus taking the figure at earthing up which is generally done after about six months from planting, the uptake of nitrogen and potash during this period has been about 40 to 50 per cent of the optimum, depending upon the treatments, while

TABLE IX

Water content

Treatment and variety	Functioning leaf						Stem		
	Water / Leaf area			Water / Dry weight			Water / Dry weight		
	Formative stage	Grand period stage	Maturity stage	Formative stage	Grand period stage	Maturity stage	Formative stage	Grand period stage	Maturity stage
POJ 2878—									
75 lb. N	0·31	0·38	0·33	3·3	2·6	1·6	7·3	4·5	2·6
150 lb. N	0·29	0·38	0·34	3·6	2·7	1·8	9·7	4·8	2·5
300 lb. N	0·30	0·39	0·34	3·2	3·3	2·1	9·6	5·3	2·9
450 lb. N	0·35	0·42	0·35	3·4	3·2	2·3	12·4	5·8	3·2
600 lb. N	0·31	0·45	0·38	3·6	3·3	2·5	15·8	6·4	3·4
Average	0·31	0·40	0·35	3·4	3·0	2·1	11·0	5·4	2·9
C. D. between any two treatments	0·120	0·026	0·106	0·970	0·49	0·47	...	0·79	0·75
Pundia—									
75 lb. N	0·32	0·43	0·30	3·5	3·1	2·2	11·0	5·4	3·6
150 lb. N	0·30	0·42	0·39	3·4	2·9	2·5	9·0	6·1	3·6
300 lb. N	0·33	0·42	0·38	3·3	3·5	3·0	9·4	7·7	4·4
450 lb. N	0·28	0·42	0·39	2·9	3·2	2·7	10·4	6·8	3·8
600 lb. N	0·33	0·39	0·37	4·1	3·2	3·1	9·1	7·5	4·3
Average	0·31	0·42	0·37	3·4	3·2	2·7	9·8	6·7	3·9
C. D. between any two treatments	0·106	0·078	0·099	0·69	0·49	0·69	...	1·98	1·26

TABLE X

Uptake of nutrients per acre in lb. 1935-36

Treatment and variety	Mid-May				Before earthing				Optimum				Percentage of nitrogen utilized
	N	P_2O_5	K_2O	CaO	N	P_2O_5	K_2O	CaO	N	P_2O_5	K_2O	CaO	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
POJ 2878—													
75 lb. N	31·9	10·1	68·3	19·4	33·1	12·1	99·2	15·8	87·7	57·1	365·0	75·2	116·9
150 lb. N	42·4	13·4	83·5	16·7	60·2	18·5	197·9	23·2	123·3	85·7	442·2	89·4	82·2
300 lb. N	32·6	8·2	82·6	16·7	57·4	9·5	137·1	25·2	227·2	121·5	580·9	177·3	75·7
450 lb. N	50·9	9·0	98·4	15·0	92·3	13·8	199·3	26·2	215·7	109·5	581·8	185·5	47·9
600 lb. N	42·3	11·1	78·5	15·7	77·3	21·5	217·5	23·0	213·0	112·8	697·1	119·4	35·5
Pundia—													
75 lb. N	25·7	8·4	58·0	10·6	34·0	9·5	102·5	15·1	79·7	71·2	364·1	93·6	106·3
150 lb. N	24·7	10·6	62·5	5·2	47·9	10·4	112·3	16·2	90·1	80·3	397·6	88·6	60·1
300 lb. N	27·7	9·1	59·9	10·1	31·9	12·5	104·6	18·0	151·2	114·3	531·9	134·5	56·4
450 lb. N	26·9	7·2	55·8	9·3	49·6	21·2	93·0	39·7	121·9	100·9	570·1	121·6	27·1
600 lb. N	22·7	6·3	52·1	10·3	29·2	17·1	92·2	20·4	132·8	89·3	408·0	113·5	22·1

that of phosphate about 15 to 20 per cent only. It will also be interesting to note that the major uptake of all the constituents takes place within three to four months after earthing up which coincides with the grand period of growth. Coming to the individual treatments the differentiation in the uptake of all the constituents is not so very evident till earthing up, i.e. up to six months, except in the case of 75 lb. N mainly in POJ 2878. This practically confirms the findings of Das [1936] who has stated that the uptake in either low, medium or high nitrogen series was the same up to about eight months when the differential effect of treatments began to manifest. In our experiments also it is only later that the differentiation is apparent and that also up to 300 lb. N the figures for higher nitrogenous series being practically similar to this treatment. In the case of Pundia there is in fact an indication of same deleterious effect on the uptake of these high nitrogenous doses. The application of a basal dressing of superphosphate at the rate of 100 lb. P_2O_5 during the next season has amended this by showing an increased uptake in these higher treatments over 300 lb. N with practically no difference in the figures for treatments up to 300 lb. N. Thus evidently while there could be a proper agrobiologic balance in the soil solution with nitrogenous top dressings up to 300 lb. N, quantities above this figure had created a disturbance in this balance.

In column 14 (Table X), the optimum uptake of nitrogen has been expressed as the percentage of the amount of N actually applied in top-dressings in different treatments. The figures are very instructive as they show that as the application of nitrogen increases the relative efficiency of its utilization decreases. Except in the lowest treatment of 75 lb. N, in which there has been actually a drain on the soil nitrogen, all other treatments have shown less uptake than the quantity of nitrogen applied. This has further varied according to the variety, Pundia being less efficient in this respect than POJ 2878. In the high N series as 450 and 600 lb. N, the percentage uptake specially in the case of Pundia is practically negligible. Even in 300 lb. N, about 44 per cent of nitrogen is not utilized in this variety, while in the case of POJ 2878 this figure comes to 25 per cent. It will be thus apparent that from the standpoint of the efficient absorption of nitrogen applied, POJ 2878 can take up higher nitrogenous dose than Pundia and that in higher nitrogenous series, much of the nitrogen so applied is not utilized by the crop. A part of it has remained no doubt in the soil and has given improved yields in the case of the rotational crop of cotton which followed the cane crop.

Minerals in cane juice and quality of gul. During 1935-36 the cane juice was periodically analysed from September onwards for mineral constituents as N, P, K, Ca, Mg and Na. In the case of N, amide N was also determined according to the method of Pucher [1935]. The data are given in Table XI. In order to reduce the size of the table, figures for the last three constituents are omitted from the table, as they did not show any variation between the treatments. From the juice obtained in the month of January, *gul* was prepared and it was similarly analysed. From the figures so obtained, the percentage constituents of the juice retained in the *gul* were calculated. The quality of this *gul* was also determined by tintometer colour standards. All these data are also included in Table XI.

These figures in combination with those for the purity of juice given in Table VII will show that the concentration of the mineral constituents in juice increases with the progress of maturity. It seems that there is a rapid translocation of them from the leaves to stems, once the growth is completed. In the case of nitrogen, simultaneously with its increased concentration there is a fall in the soluble nitrogen, which indicates synthesis of proteins. Coming to the individual treatments, there is an increase in total nitrogen with consequent increase in soluble nitrogenous compounds with the graduated nitrogenous doses. The reverse is, however, the case with phosphate, while potash seems to be practically similar in all the treatments during most of the periods. Among the varieties, *Pundia* shows a much lower concentration of all these mineral constituents than POJ 2878. Further, the ratio of N/P_2O_5 is approximately one in this variety as against two in the other case. Similarly the ratio of N/K_2O is lower in Pundia. Among the treatments the ratios, specially of N/P_2O_5 widen with increased nitrogenous manuring. The analyses of *gul* show that a higher percentage of nitrogen is removed by precipitation during the process of manufacture of *gul* in the case of Pundia than in POJ 2878 in which specially the *gul* from the higher nitrogenous treatments retains a greater proportion of nitrogen. On the other hand in these higher treatments, there is a greater loss of glucose which may be due to the destructive action of alkali salts. It is still a moot point, however as to how far these reactions are responsible for the quality of *gul*

TABLE XI

Per cent mineral constituents in juice and gul *1935-36*

Treatment and variety	N			P_2O_5			K_2O			Amide N Percentage of total N			Per cent constituents retained in *gul* from juice					Colour ratios yellow / red
	Sept.	Nov.	Jan.	Sept.	Nov.	Jan.	Sept.	Nov.	Jan.	Sept.	Nov.	Jan.	Total N	P^2O_5	K^2O	Amide N	Glucose	
POJ 2878—																		
75 lb. N .	·0079	·0065	·016	·0225	·0155	·0173	·209	·236	·270	5·4	8·2	9·1	56·4	76·0	38·3	13·3	82·8	3·4
150 lb. N .	·0136	·0085	·024	·0130	·0131	·0181	·258	·284	·300	7·1	7·6	8·3	51·5	84·0	39·1	19·1	74·9	3·1
300 lb. N .	·0210	·0161	·023	·0094	·0079	·0139	·175	·219	·252	17·1	9·4	8·7	86·9	85·8	80·1	11·7	62·9	2·6
450 lb. N .	·0369	·0370	·049	·0095	·0128	·0159	·187	·242	·291	19·9	14·3	13·9	75·2	80·5	78·3	8·3	56·8	2·1
600 lb. N .	·0395	·0290	·069	·0071	·0141	·0149	·150	·248	·235	21·7	23·1	14·5	84·3	59·0	88·8	14·1	52·9	2·2
Pundia—																		
75 lb. N .	·0076	·0049	·0099	·0094	·0136	·0158	·197	·161	·152	...	11·0	5·2	45·2	89·8	82·3	18·1	77·7	4·0
150 lb. N .	·0075	·0073	·0083	·0146	·0158	·0153	·150	·169	·150	10·9	8·2	6·5	70·6	77·4	91·6	18·8	50·0	3·9
300 lb. N .	·0082	·0129	·0189	·0094	·0128	·0125	·142	·153	·200	16·0	13·0	12·3	53·3	77·1	80·5	8·7	60·6	3·9
450 lb. N .	·0260	·0137	·0208	·0144	·0122	·0116	·137	·150	·176	16·8	26·4	13·0	55·8	62·9	85·1	9·4	28·8	3·2
600 lb. N .	·0240	·0280	·0307	·0113	·0145	·0120	·133	·178	·216	21·0	13·9	15·0	49·0	56·3	66·9	9·7	36·3	3·2

is judged by its colour. According to the market standard yellow colour fetches a greater price and the higher ratio of yellow to red thus indicates a better quality. A close relationship of the ratio of N/P_2O_5 in the juice from the different treatments and the colour standards of *gul* obtained from it is, however, visible. That the presence of phosphate improves the colour of *gul* is further confirmed by a practical method of addition of superphosphate to low-quality juice just before the striking point of *gul* in order to secure this yellow colour.

Availability of nutrients. **This has been estimated** in the case of nitrogen only by the analysis of soil for nitrates. This method was generally followed till the formation of cane when the exudation method of Weller [1931] was adopted in order to determine the availability of N as well as the other two nutrients of P and K. In order to secure the exudate, all the canes of the stool are cut and connected with a sterile flask with sterile tubes and the exudate so obtained from four such stools were analysed, for these three constituents by the colorimetric method of Steenkamp [1934]. Soil nitrates have in general shown a higher gradient with higher nitrogenous treatments with its accumulation in the balk. It is thus evident that nitrates thus formed are not all utilized by the crop during this period. The exudation studies (Fig. 3) have further revealed that POJ 2878 is capable of securing higher quantity of mineral nutrients than Pundia except in the case of P_2O_5. This can be ascribed to the differences in the root system of the two varieties already described by Rege and Wagle [1941]. Owing to the greater depth of root penetration POJ 2878 is able to tap lower soil depths. Similarly the thin profusely branching root system has been of advantage to Pundia in the case of P_2O_5 which would be more available in the surface soil layers owing to the basal application of superphosphate to all the treatments during this season. In the absence of similar analysis during previous years, when phosphatic manuring was not resorted to, it is very difficult to say whether normally Pundia would have shown a higher availability of P_2O_5 as observed during this season. Coming to the individual treatments, the availability of all these nutrients is at its maximum between June and August in the case of POJ 2878 and a month later in Pundia. In the treatments above 300 lb. N, these nutrients continue to be available even much later. While the rise in the availability of nitric N, between June and August is explicable by the dose of nitrogenous top-dressing applied in June at the time of earthing, similar rise in the case of P_2O_5 and K_2O indicates mainly the period required by these constituents in the soil to become available although there may be some contribution from the oilcakes applied in top-dressings. This maximum availability of all these nutrients closely corresponds with the grand period phase of the plant growth when the major absorption by the plant takes place. These findings may explain the reason why the standard chemical and plant methods

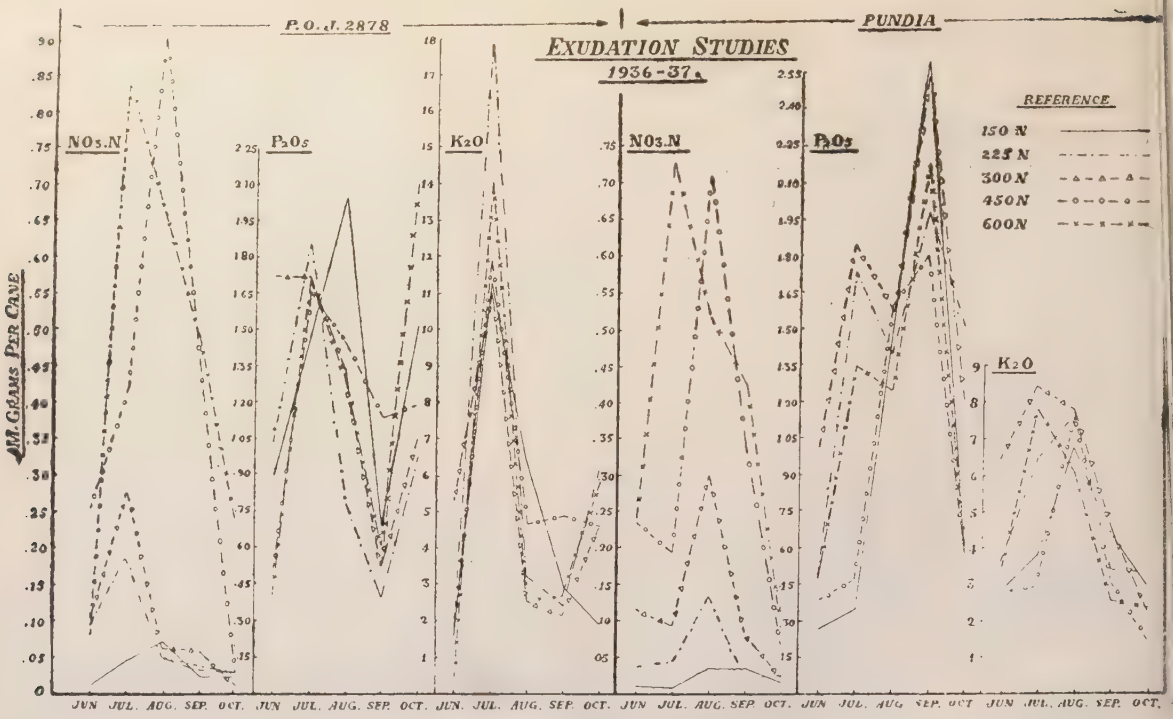

FIG. 3. Exudation studies—1936-37

for determining available P_2O_5 do not always give consistent results about the phosphatic status of the soil in the case of such a long-term crop as sugarcane. The exudation studies have also revealed the cause of the variation in the ratios of N to other constituents in the plant in the different treatments. It will be seen that while curves for P_2O_5 and K_2O are similar in the case of all the treatments, there is a big difference in the case of N with a definite gradient according to the treatments. Thus a higher quantity of P_2O_5 or K_2O will be available for absorption per unit N in the case of lower nitrogenous series than in the higher ones.

SUMMARY AND CONCLUSIONS

The problem of the nitrogen fertilization of sugarcane is of extreme importance in the Deccan Canal Tract, as the cultivation of the crop involves a large expenditure on nitrogenous top-dressings alone. In the present research work on January-planted cane, the treatments varied from 75 to 600 lb. N in graduated doses and the paper embodies the results of these treatments on the development of the plant, sucrose formation and mineral uptake which are summarized below:

(1) Practically all the plant phases are favourably influenced by nitrogenous manuring. In the case of germination an application of quick acting fertilizer as sulphate of ammonia is effective, the minimum dose for securing optimum germination being 15 lb. N at the time of planting. Increasing this dose even up to 60 lb. N has been of no further advantage.

(2) The tillering capacity is dominated by the concentration of nitrogen in the soil solution, and both low as well as high concentration affect this phase adversely the first by lowering its activity and the second by increasing it to abnormal proportions. The higher limit also differs for the varieties, POJ 2878 standing a higher concentration than Pundia among the two varieties under study. A nitrogenous dose supplying between 50 and 100 lb. available N is found to be the optimum one for this phase.

(3) Although the relative growth rate is practically similar in all the treatments except in the case of the lowest dose of 75 lb. N, it is in the continuation of growth that the effect of increasing applications of nitrogen is visible. The differentiation between the treatments appears after about eight months when the growth in the lower nitrogenous series practically ceases.

(4) Nitrogen favours increase in the number of functioning leaves as well as the length and width of the leaf. Although there is no sign

icant increase in the rate of carbon assimilation vith increased nitrogenous doses the total ynthesis of carbohydrates are expected to be igher owing to increased leaf area. Further itrogen promotes succulence in cane, i.e. there s more water per gram of dry matter. The ptimum limit of nitrogen for all these beneficial hysiological characteristics appears to be 300 b. N, higher nitrogenous doses showing in most ases insignificant variation from this treatment.

(5) Estimation of the relative contribution to he total cane tonnages has shown that the first rder stalks contribute only 30 to 35 per cent in he case of POJ 2878 and 15 to 20 per cent in undia, the rest being practically made up by he tillers formed in April and May. It has een further observed from the weight of the ndividual canes that generally the growth of he first order stalks is poorer than that of April-ormed tillers. In higher nitrogenous series similar results are also obtained in May-formed illers in the case of Pundia.

(6) Increasing application of nitrogen increases he cane tonnages but decreases the concentra-ion of sucrose in the expressed juice. It is bserved that owing to short period of climate avourable to sucrose formation, delaying of arvest does not help in the formation of maxi-num sucrose in higher manuring. The com-nercial cane sugar per acre is a good criterion or fixing the limits of nitrogenous top-dressings vhich, however, vary according to the inherent haracteristic of sucrose development. Thus, while in the case of early maturing variety as POJ 2878 one can go up to 600 lb. N, this last dose of nitrogen is definitely deleterious in the ase of late maturing variety as Pundia. Similar will be the result with Co. 419 which is the eading cane in the Deccan Canal Tract as it is lso a late-maturing variety. On economic con-iderations 300 lb. N, seems to be the optimum dose for the January planting in the case of all he varieties.

(7) Calculation of the water content of the eaf, both on dry weight basis and on leaf area, as given contradictory results owing to the ncrease in dry weight per unit leaf area with dvancing age. From the standpoint of the hysiological processes the latter method of alculation is found to be more suitable than he former.

(8) Studies in the mineral uptake have shown he differentiation in the percentage uptake only n the case of nitrogen which is very clear at ater stages of grand period and at the maturity tage. The percentage uptake of other utrients is practically similar for all treat-ments, and this creates an unbalanced nutrition resulting in continued growth and low sucrose formation in higher nitrogenous doses. The figures for uptake per acre have shown that the optiumn uptake of all these constituents is completed between October and December depending upon the treatments. Out of this, about 40 to 50 per cent in the case of N and K_2O and 15 to 20 per cent of P_2O_5 and CaO are taken up during the first six months, i.e. before earthing up. These findings are of greater importance in the evolution of an efficient system of manuring. As the cane attains maturity all the constituents shown a fall and this shows that harvesting the crop at its maximum maturity besides giving higher yields of sugar or *gul* will also contribute to greater economy as less plant food is removed. Among the principal elements potash is taken up to the greatest extent and phosphates the least, the uptake of nitrogen and calcium being intermediate. Estimation of the per cent up-take from nitrogenous top dressing has shown a decrease with increasing doses, Pundia being the least efficient in this respect.

(9) The concentration of the mineral cons-tituents in the expressed juice increases with the progress of maturity as a result of the rapid translocation of these from the leaves to stem, once the growth is completed. With increasing application of nitrogen there is an increase in total as well as soluble nitrogen and decrease in the phosphate content. Among the varieties, Pundia shows a much lower concentration of all these mineral constituents in the juice with a lower ratio of N/P_2O_5. The good coloured *gul* obtained in this variety appears to be due to this.

(10) Availability of nutrients has been studied both by periodical soil analysis for nitrates and exudation studies for all the major nutrients. The latter method has revealed that POJ 2878 is capable of obtaining higher quantity of mineral nutrients than Pundia owing to the greater depth of the root penetration. The availability of all the nutrients is at its maximum during June to August in the case of POJ 2878 and a month later in Pundia. While this maximum availability of nitrogen is explic-able by the big dose of nitrogenous top-dressing which the crop receives in June at the time of earthing up, such a late availability in the case of the other constituents indicates the time required by these soil constituents to come into soil solution, although there may be some con-tribution from the oil cakes applied at the time of earthing. This time coincides with the major uptake of all its nutriment by the plant and

this seems to be the reason why the standard chemical and plant methods for determining available P_2O_5 do not always give consistent results about the phosphatic status of the soil in the case of such a long-term crop as sugarcane.

REFERENCES

Anonymous (1929). Sugarcane. *Bombay Dept. Agric. Leaflet No. 17*

Basu, J. K. and Sirur, S. S. (1937). Soils of the Deccan Canals, I. Genetic Soil Survey and Soil Classification: Nira Right Bank and Pravara Canals. *Indian J. agric. Sci.* **8**, 637

Das, U. K. (1936). Nitrogen nutrition of sugarcane. *Plant Physiology*, **11**, 251

Dutort, J. L. and Beaker, B. F. (1939). A study of plant food absorption. *Facts about Sugar* **34**, 33

Fisher, R. A. (1932). *Statistical methods for Research Workers.* Oliver and Boyd, 4th Edition

Ganong, W. O. (1908). *A Laboratory Course in Plant Physiology.* Henry Holt & Co., New York

Gregory, F. G. (1926). The effect of climatic conditions on the growth of barley. *Ann. Bot.* **40**, 1

Gregory, F. G. and Richards, F. J. (1929). Physiological studies in plant nutrition, I. The effect of manurial deficiency on the respiration and assimilation in barley. *Ann. Bot.* **43**, 119

Pucher, G. W., Leavenworth, C. S. and Vickery, H. B. (1935). Determination of ammonia and amide nitrogen in plant tissues. *Ind. & Eng. Chem. Anal.* F. D. 7, 152

Russel, E. J. (1937). *Soil conditions and plant growth.* Longmans Green and Co., London

Rege, R. D. and Sannabhadti, S. K. (1943). Problems of Sugarcane Physiology in the Deccan Canal Tract, IV. Mineral Nutrition. (A) Phosphates. *Indian J. agric. Sci.* **13**, 87

Rege, R. D. and Wagle, P. V. (1939). Problems of Sugarcane Physiology in the Deccan Canal Tract, I. Germination. *Indian J. agric. Sci.* **9**, 423

———— (1941). Problems of sugarcane physiology in the Deccan Canal Tract, III. Root System. *Indian J. agric. Sci.* **11**, 368

Steenkamp, J. L. (1934). Recent development in soil analysis. *Imp. Bur. Sci.* No. **5**, 5

Weller, D. M. (1931). Root pressure and root pressure liquids of the sugarcane plant. *The Hawaiian Planters' Rec.* **35**, 349

STUDIES IN THE PERIODIC PARTIAL FAILURES OF THE PUNJAB-AMERICAN COTTONS IN THE PUNJAB

X. THE INTERRELATION OF SOWING-DATE, NITROGEN, WATER-SUPPLY AND SPACING ON GROWTH AND YIELD OF 4-F COTTON*

By R. H. Dastur and Mukhtar Singh, Punjab Agricultural College, Lyallpur

(Received for publication on 23 September 1942)

The results discussed in the preceding contribution [Dastur and Mukhtar Singh, 1943] showed that nitrogen was the determining factor for growth and yield of the cotton crop on light sandy soils, and water supply was of secondary importance. But, when the level of fertility was high, water supply also became a limiting factor. Consequently, the best development and the maximum yields were obtained when levels of both of these factors were simultaneously raised.

Applications of sulphate of ammonia as a general ameliorative measure for *tirak* caused by nitrogen deficiency involves a practical difficulty. Light sandy soils are interspersed with those possessing alkaline or saline subsoil. While the former respond so well to nitrogen, the latter are insensitive to its use. The magnitude of response in a particular field would, therefore, depend upon the relative distribution of the two soil types, other conditions being constant. Consequently, the problem of manuring is rendered complicated.

One of the methods of approach to meet this situation was to devise alternative ways for raising crop yields without recourse to artificial applications. The most practical way of accomplishing this was conceived to be delayed sowing. This aimed at economic utilization of the available nitrogen and water by reducing the plant size.

Deficiency of nitrogen and consequently *tirak* may well be minimized by delayed sowing but it may also lower the yields by reducing the size of the plants, since yield depends on the plants' scaffolding as well. Thus what may be gained in boll size may be lost in boll number and at times the loss might even exceed the gain. It was, therefore, necessary to examine the problem of spacing in relation to sowing date.

The foregoing considerations necessitated the introduction of sowing date and spacing factors in addition to nitrogen and water, in the 1939-40 experiment. Phosphorus and potash were omitted as they did not produce appreciable increases in yield in any of the previous experiments.

There is lack of published data on the interrelation of above-mentioned factors for the Punjab or India. This type of work has, however, been done in the Sudan in recent years with useful

*The investigations described in this paper were carried out in the Punjab Physiological (Cotton Failure) Scheme financed jointly by the Indian Central Cotton Committee and the Punjab Government

results [Gregory *et al.* 1932; Lambert and Crowther, 1935]. Additional features of the studies presented here are that they are supported by developmental data and have been made in relation to the soil conditions.

Description of the experiment

This experiment was conducted on light sandy soil in the rotation—wheat—*toria*—cotton. The treatments were all combinations of:

Factors	Sowing date	Nitrogen	Water	Spacing
Levels	d_1 = 12/5/39 d_2 = 2/6/39 d_3 = 22/6/39	o = Control n = 50 lb. N. per acre on 14/8/39	w_1 = Normal wtgs. w_2 = Heavy wtgs. from mid-August	s_1 = 2 ft. × 1½ ft. s_2 = 2½ ft. × 2½ ft.

It was necessary to reduce the block size by confounding. A balanced arrangement in six 12-plot blocks, as developed by Yates [1937], was adopted.

The plot size at sowing was 32½ ft. × 60½ ft. = 1/22·1 acre, accommodating 16 rows in S_1 and 13 in S_2 plots. The size of the plot for yield was 14 ft. × 48 ft. = 1/64·8 acre and 12½ ft. × 47½ ft. = 1/81·5 acre in S_1 and S_2 plots, respectively. Part of the plot area at borders was rejected as non-experimental and the rest utilized for dry-weight sampling.

It may be noted that sowings were spaced at an interval of 20 days. Plots designated as *d*1, *d*2 and *d*3 received 7, 6 and 5 irrigations respectively. The first irrigation was applied in the 5th week after sowing in all cases. Subsequent waterings were given at intervals of 20 days approximately. For uniformity of conditions and agricultural convenience. This plan enabled the irrigation for the different sowings to fall on the same day.

General observations. The season 1939-40 was characterized by a long spell of heat and will be remembered for its dryness. But there were no visible symptoms of abnormal desiccation on the plants even under normal conditions of watering on this type of soil. The plants began to turn yellow even before the middle of August. Nitrogen application revived them in colour, freshness and lustre after a week, and slowly and gradually expressed itself in growth. The condition of the unmanured plants went from bad to worse. Even the fruiting parts were chlorotic. Late-sown plots were darker and greener when compared with the early-sown at the same stages of morphological development, and so were the widely-spaced plants in comparison to the thickly-spaced ones.

Experimental results

A great deal of developmental data at periodic intervals were collected. The values at the final stage and the aggregate yields were subjected to statistical analysis appropriate to the design. Table I shows at a glance the significant effects in case of the yield and the different vegetative and the reproductive characters.

The main effects of all the four factors on the different characters are significant, except those of water on flower production, boll number and node number, and of spacing on boll weight and yield. Of the first-order interactions those involving watering are not significant and all others, viz. sowing date × spacing, sowing date × nitrogen and spacing × nitrogen, merit consideration as they appear significant, in one form or the other, in the development of the plant. Of the high-order interactions, D × S × N alone deserves a reference.

All the main effects and the significant interactions on the basis of the statistical analysis have been presented in the form of summary tables, for the vegetative characters and the reproductive characters. Main differences with the corresponding standard errors are also given. Significance of the differences is indicated by asterisks as usual.

Dates. The dates have influenced significantly the entire plant development (Table II). The nature of responses, however, is dissimilar for the different characters. As the three sowings were equally spaced, the two comparisons corresponding to dates have been split up into the linear and the quadratic responses. The linear measures the response to 40 days' delay in sowing and is given by $d3 - d1$. The quadratic is a measure of curvature or deviation of the behaviour of the central sowing from the linear trend, and is given by $d_3 - 2d_2 + d_1$.

In the case of height the linear component is significant. The plant height decreases with delay in sowing but the decline is not progressive. The linear behaviour is conditioned and the quadratic response comes out significant.

The quadratic component is again significantly revealed in case of internodal length since the central sowing has given the longest internodes, the extreme sowings giving equal. Node production falls off successively from the first to the last sowing but not proportionately. The decrease is more rapid after the second sowing. In case of dry weight per plant or per square yard as well as flower production, the decline with delay in sowing is definitely linear and the quadratic component is suppressed.

The direction of effect on the setting percentages is the reverse of that on flower production. The percentage of flowers maturing into bolls

TABLE I

'F' values of the significant effects for the vegetative and the reproductive characters

Due to	D. F.	Height	No. of nodes	Internodal length	Dry wt. per plant	Flowers	Boll number	Boll weight	Yield of *kapas*
		**	**		**	**	**	**	*
D′¹	1	45·63	188·5	...	230·8	221·5	15·79	13·80	5·95
		**	*	**					**
D¹¹	1	29·97	6·8	28·99	...	...	3·97	...	8·81
		**	**	**	**	**	**	**	**
N	1	92·53	81·9	43·36	156·4	130·6	75·2	35·11	159·74
		**		**	*			*	*
W	1	11·65	...	7·88	6·27	...	...	5·38	4·01
		**	**	**	**	**	**		
S	1	41·42	67·1	10·42	142·61	26·3	9·9	...	...
					**	**		**	**
D × N	2	...	...	...	18·31	7·44	2·59	7·42	7·50
D × W	2	...	...	...	....	...	...	...	...
		**	**	*	**		**		
D × S	2	7·39	8·4	4·19	12·31	...	5·56	...	...
N × W	1	...	...	...	...	...	...	...	...
		*		**		*		*	*
N × S	1	5·38	...	8·65	...	5·84	...	5·73	6·33
					**				
W × S	1	...	...	...	10·51	...	...	...	...
D × N × W	2	...	...	...	...	...	...	...	...
							*		
D × N × S	2	...	...	...	...	...	3·56	...	...
D × W × S	2	...	...	...	...	...	...	...	...
N × W × S	1	...	...	...	...	...	...	...	...
D × N × W × S	2	...	...	...	...	...	...	...	...

* = Significant at 5 per cent level ** = Significant at 1 per cent level

TABLE II

Main effects of sowing date on the vegetative and the reproductive characters

	Height (cm.)	No. of nodes	Inter-nodal length (cm.)	Dry wt. per plant (gm.)	Dry wt. per sq. yard (gm.)	Flowers per sq. yard	Setting percent-age	Bolls per sq. yd.	Seed cotton per boll	Yield in md. per acre
d_1	81·9	35·7	2·28	237	482	261	25·5	55·1	1·365	11·17
d_2	84·1	34·2	2·45	181	370	203	29·4	54·5	1·515	12·01
d_3	71·0	31·2	2·27	118	248	132	36·3	45·4	1·573	9·66
	**	**		**	**	**	**	**	**	*
D¹	*—10·94*	*—4·52*	*—0·006*	*—118·9*	*—233·8*	*—128·8*	*+10·83*	*—9·68*	*+0·208*	*—1·51*
	**	*	**							**
D¹¹	*—15·36*	*—1·48*	*—0·354*	*—06·8*	*—9·8*	*—13·4*	*+2·95*	*—8·42*	*—0·092*	*—3·19*
S. E. (1¹) (for D¹)	±1·62	±0·33	±0·038	±7·8	±20·2	±8·65	±1·06	±2·44	±0·056	±0·601
S. E. (2) (for D¹¹)	±2·80	±0·57	±0·066	±13·6	±35·0	±14·99	±1·84	±4·22	±0·096	±1·043

increases steadily as the sowing date advances. Higher setting percentages in the later sowings have improved their status so far as boll numbers are concerned. This is why, the decrease in boll number is inappreciable from the first to the second sowing, nevertheless the reduction is still substantial in the third sowing. Thus the compensation has been inadequate in case of the last sowing The quadratic response to dates on boll-number is, therefore, on the verge of significance.

As in the case of setting percentage, the linear response to dates on boll size is positive and significant. The gradual increase in boll size with delay in sowing have affected the yield performance of the sowing dates. The second sowing has given the maximum yield. However, the yield in the third sowing in spite of the maximum boll weight continues to be lower than the first two sowings. The reason for this decline in yield will be clear later when the interactions of dates with spacing and nitrogen are considered.

Nitrogen. The dominating influence of nitrogen on growth, amelioration of *tirak*, and improvement in yield is clearly established by the results of this experiment (Table III). The evidence obtained fully confirms the previous findings [Dastur and Singh, 1943] and needs no further elaboration. It is, also noteworthy that the setting percentage is unaffected by nitrogen.

TABLE III

Main effects of nitrogen on the vegetative and the reproductive characters

	Height (cm.)	No. of nodes	Inter-nodal length (cm.)	Dry wt. per plant (gm.)	Dry wt. per sq. yard (gm.)	Flowers per sq. yard	Setting percent-age	Bolls per sq. yd.	Seed cotton per boll	Yield in md. per acre
o	72·7	32·4	2·23	139	279	158·1	30·41	43·04	1·349	7·95
n	85·4 **	34·9 **	2·44 **	219 **	455 **	238·9 **	30·34	60·29 **	1·620 *	13·95 **
Diff.	*+12·72*	*+2·43*	*+0·204*	*+79·9*	*+175·3*	*+80·8*	*—0·07*	*+17·25*	*+0·271*	*+6·00*
S. E.d.	±1·32	±0·27	±0·031	±6·4	±16·5	±7·07	±0·87	±1·99	±0·045	±0·491

Watering. Heavy watering has neither affected the production of flowers nor of bolls but it has increased significantly the height through elongation of internodes and the yield through improvement in boll size (Table IV). The magnitude of increase in yield is, however, very small but as none of the interactions of watering have come out significant, this small increase is consistently obtained at all levels of the other factors.

TABLE IV

Effect of water on the vegetative and the reproductive characters

	Height (cm.)	No. of nodes	Inter-nodal length (cm.)	Dry wt. per plant (gm.)	Dry wt. per sq. yard (gm.)	Flowers per sq. yard	Setting percent-age	Bolls per sq. yd.	Seed cotton per boll (gm.)	Yield in md. per acre
w_1	76·8	33·4	2·29	171	357	203·6	31·13	51·51	1·431	10·44
w_2	81·3 **	33·9	2·38 **	187 *	377	193·5	29·62	51·82	1·537 *	11·45 *
Diff.	*+4·51*	*+0·47*	*+0·087*	*+16·0*	*+19·3*	*—10·1*	*—1·51*	*+0·31*	*+0·106*	*+1·01*
S. E.d	±1·32	±0·27	±0·031	±6·4	±16·5	±7·07	±0·87	±1·99	±0·045	±0·491

Spacing. When the plants are widely spaced the growth in extension as well as dry matter per plant is significantly greater than when spaced closely (Table V). This is to be expected as, plant for plant, greater resources, e.g. light, nutrients, water, etc., are at the disposal of individuals. When the production of dry matter is considered on the area basis, the reverse condition obtains. The compensatory growth due to wide spacing does not adequately cover the loss of plant number. The same relation holds in case of flowers or boll production per square yard. There is, also, suggestive increase in yield under close spacing.

TABLE V

The main effect of spacing on the vegetative and the reproductive characters

	Height (cm.)	No. of nodes	Inter-nodal length (cm.)	Dry wt. per plant (gm.)	Dry wt. per sq. yard (gm.)	Flowers per sq. yard	Setting percent-age	Bolls per sq. yard	Seed cotton per boll	Yield in md. per acre
s_1	74·8	32·6	2·29	141	422	216·7	30·28	54·79	1·486	11·31
s_2	83·3 **	34·8 **	2·39 **	217 **	312 **	180·4 **	30·47	48·53 **	1·483	10·58
Diff.	*+8·51*	*+2·20*	*+0·100*	*+76·3*	*—109·9*	*—36·3*	*+0·19*	*—6·26*	*—0·003*	*—0·73*
S. E.d.	±1·32	±0·27	±0·031	±6·4	±16·5	±7·07	±0·87	±1·99	±0·045	±0·491

The main effects discussed above are averaged over all levels of the remaining factors. When the effects vary with the change in the level of the other factors, the main effects are misleading if no reference is made to the interactions. It is, therefore, necessary to study the differential responses by two-way tables.

Sowing date and nitrogen. The effect of nitrogen on height, node number and internodal length under the three sowings individually shows that the responses are all highly significant and are virtually similar under the different sowings (Table VI). There is thus little evidence of differential behaviour on any of these characters.

TABLE VI

Interaction : sowing date and nitrogen

Height (cm.)				Node number				Internodal length (cm.)			
	d_1	d_2	d_3		d_1	d_2	d_3		d_1	d_2	d_3
o . . .	75·0	77·0	66·0	*o* . . .	34·5	32·7	30·1	*o* . . .	2·17	2·35	2·19
n . . .	88·8	91·3	76·0	n . . .	36·8	35·6	32·2	n . . .	2·40	2·56	2·36
diff. ±2·29 . .	** +13·8	** +14·3	** +10·0	diff. ±0·465 .	** +2·3	** +2·9	** +2·1	diff. ±0·054 .	** +0·23	** +0·21	** +0·17

The case with growth as measured by dry weight per plant or per square yard is different (TableVII a & b). Though increase due to nitrogen is substantial and highly significant in all sowings, the response to nitrogen shows a progressive and proportionate decline with each deferred sowing.

TABLE VII

Interaction : Sowing date and nitrogen

(*a*) Dry wt. per plant (gm.)				(*b*) Dry wt. per sq. yd.				(*c*) Flowers per sq. yard			
	d_1	d_2	d_3		d_1	d_2	d_3		d_1	d_2	d_3
o . . .	173	142	102	*o* . . .	345	281	212	*o* . . .	211	153	111
n . . .	301	220	135	*n* . . .	619	460	285	*n* . . .	310	253	153
Diff. ±11·07 .	** +128	** +78	** +33	Diff. ±28·6 .	** +274	** +179	* +73	Diff. ±12·2 .	** +99	** +100	** +42

(*d*) Bolls per sq. yard				(*e*) Seed cotton per boll (gm.)				(*f*) Yield of seed cotton md. per acre			
	d_1	d_2	d_3		d_1	d_2	d_3		d_1	d_2	d_3
o . . .	45·6	43·6	39·9	*o* . . .	1·125	1·375	1·548	*o* . . .	7·25	8·57	9·02
n . . .	64·6	65·3	51·0	*n* . . .	1·605	1·655	1·599	*n* . . .	15·10	15·45	11·31
Diff. ±3·44 .	** +19·0	** +21·7	** +11·1	Diff. ±0·079 .	** +0·480	** +0·280	+0·051	Diff. ±0·85 .	** +7·85	** +6·88	** +3·29

These relations can be understood in terms of growth behaviour of the three sowings. Mention has already been made of the decreasing dry weights at the final stage, as the sowings are delayed. Early sowing has the advantage of time for the production of larger scaffolding before the N-application made in August begins to take effect. Correlated with this are the signs of internal starvation. Both of these conditions increase potentialities of the early sowings for further increase in dry matter through nitrogen applications. These pre-requisities are wanting in the late sowing and their absence renders them less responsive to nitrogen. It is interesting to note that similar interaction effect has not come out significant in the case of height. Height measures the growth of the apical meristem of the main axis only. There are similar growing points all over the plant, and it can be inferred, from the absence of D×N interaction in case of height, that each of them will grow with nitrogen to the same extent irrespective of the time of sowing. But the number of points to elongate and thicken are more in the case of early sowings, so the increase due to nitrogen in the total dry matter is also greater. Less and less points are benefited in case of later sowings and the response is correspondingly low. So the effects on height and dry weight, though apparently different, prove essentially the same phenomenon.

The differential responses to nitrogen in yield with shifts in sowing dates can be followed up step by step from the data presented in Table VIII(c-f). The three sowings have not behaved alike in their responses to nitrogen in flowering. The first two have profited equally and the magnitude of increase in the third is much lower.

Similar effect is noticeable in case of boll number.

The improvement in boll weights with nitrogen falls off progressively and proportionately as cotton is sown successively later. This is so because the boll size rises rapidly from the first to the last sowings in the absence of nitrogen, while application of nitrogen tends to maintain the boll weight at 1·60 gm. nearly in all the sowings. In the absence of nitrogen, *d3* is able to nourish

about as big a boll as any of the three sowings with nitrogen, and hence the last sowing is the least benefited by its application. It is thus clear that sowing date and nitrogen are identical in their effect in bringing about better maturity of bolls, and the effect of one is absorbed in that of the other. When two factors work in the same direction, the law of diminishing utility operates because some other factor becomes limiting.

The combined effect of treatments on boll number and boll weight appears in yields. The increase in the production of *kapas* (seed cotton) with nitrogen is less and less marked as sowings are shifted towards June but the fall is more rapid after the central sowing.

Sowing date and spacing. A study of the effect of spacing under the three sowings (Table VIII) reveals that the capacity for compensatory growth due to wide spacing varies with the date of sowing. The first two sowings tend to produce taller plants, more nodes, and longer internodes under wide spacing while the last sowing is scarcely affected by spacing. Between the first two sowings, strangely enough, the increase is greater in the second. This behaviour is associated with the greater increase in the length of the internodes, rather than their number, under the central sowing date as compared with the first.

The interaction, sowing date × spacing, is again highly significant on dry weight per plant (Table IX-a). The nature of effect is, however, slightly different. The increase in dry weight per plant by wide spacing falls progressively in the direction of late sowing and this result resembles, in all respects, the relation between sowing date and nitrogen. Thus reduction in plant number results in the operation of compensatory mechanism which becomes less and less efficient as sowing is delayed.

TABLE VIII

Interaction : sowing date and spacing

	Height (cm.)			Node number				Internodal length (cm.)			
	d_1	d_2	d_3		d_1	d_2	d_3		d_1	d_2	d_3
s_1	77·1	77·1	70·1	s_1 . . .	34·3	32·6	30·8	s_1 . . .	2·23	2·35	2·28
s_2	86·8	91·2	71·9	s_2 . . .	37·1	35·7	31·5	s_2 . . .	2·33	2·56	2·27
	**	**			**	**				**	
Diff. ±2·29 .	+9·7	+14·1	+1·8	Diff. ±0·465	+2·8	+3·1	+0·7	Diff. ±0·054	+0·10	+0·21	—0·01

TABLE IX

Interaction : sowing date and spacing

	(*a*) Dry wt. per plant			(*b*) Dry wt. per sq. yard (gm.)			
	d_1	d_2	d_3		d_1	d_2	d_3
s_1	181	141	101	s_1 . . .	542	422	302
s_2	294	222	136	s_2	422	319	195
	**	**	**		**	**	**
Diff. ±11·07 . .	+113	+81	+35	Diff. ±28·6 . .	—120	—103	—107

The failure of the internodes of the third sowing to elongate with wide spacing, even though dry weight increases, can be explained in terms of the operation of some other factors. There is freer movement of hot and dry air in widely-spaced plants of the last sowing and individual plants are subject to high insolation. The desiccation effects thus produced counteract the advantages of better supply of water and nutrients from below, and thereby limit extension growth of the main axis, but these potential resources attending wide spacing definitely contribute to increase the dry matter in the third sowing also though the increase is comparatively small.

When the results are expressed on area basis (Table IX-b), wide spacing gives significantly lower values than the close one and all decreases are of the same order under the three sowings. There is thus no interaction in case of total dry matter per square yard. Close spacing and early sowing are analogous in their behaviour with regard to the production of dry weight per unit area. Close spacing is capable of exploring the natural resources more efficiently than the wide one by virtue of the increased number of individuals, while early sowing has the advantage of time which enables extensive root growth and exposure to more hours of illuminations. Maximum dry

weight is produced under the earliest sowing with close spacing. Every delay in sowing by 20 days or the adoption of wide spacing lowers the output of dry matter by about 100 gm. till minimum is obtained under $d_3 s_2$.

Reference has already been made under main effects to the superiority of close spacing in raising the yield and the boll number. On further analysing the data, it is seen (Table X) that no special advantage has accrued to the first two sowings in regard to boll number and yields by close spacing. The third sowing alone has significantly profited by close spacing.

It has just been mentioned that consistently higher dry weights per square yard have been obtained in this experiment with close spacing as compared with the wide in all the sowings, while in case of reproductive development close spacing has benefited the third sowing only. This shows that surplus dry matter, beyond a certain maximum, is ineffective and plays no vital role in the economy of the plant. Wide spacing and late sowings produce plants which are, weight for weight, efficient for the production of *kapas*. The smaller the size of the plant the greater is its efficiency for the production of seed cotton (Table X-c). At the same time it may be pointed out that, though late-sown widely-spaced plants possess the maximum efficiency, compensation is inadequate under this treatment.

TABLE X

Interaction : sowing date and spacing

(*a*) Bolls per sq. yd.				(*b*) Yield (md. per acre)				(*c*) Seed cotton per 100 gm. of dry matter			
	d_1	d_2	d_3		d_1	d_2	d_3		d_1	d_2	d_3
s_1 . . .	56·2	54·9	53·2	s_1 . . .	11·22	12·20	10·53	s_1 . . .	13·65	19·53	23·46
s_2 . . .	54·0	54·0	37·6	s_2 . . .	11·13	11·82	8·79	s_2 . . .	16·28	24·38	30·36
			**				**				
Diff. ±3·44 .	—2·2	—0·9	—15·6	Diff. ±0·85 .	—0·09	—0·38	—1·74				

Thus below a certain minimum dry weight, gain in efficiency fails to cover the loss in yield caused by reduced bearing due to small size of the plants. This lower limit is indicated at about 325 gm. per square yard in the present case (Table IX-b).

The manner of adjustment, by which a small-sized plant tends to equal or excel in yield the one with larger structure, takes the form of modification in the relative distribution of total dry matter in parts as given in Table XI which is self-explanatory. The case of nitrogen, which raises the dry weight of the plants and still increases their efficiency, would seem paradoxical. The cause for this is to be sought in the nutritional disorder that nitrogen corrects.

Nitrogen and spacing. The results showing the interrelations of nitrogen and spacing are consolidated in Tables XII and XIII.

TABLE XI

Percentage distribution of total dry matter in parts

(Plants sampled on 28 October)

	$d_1 s_1$	$d_1 s_2$	$d_1 s_1 n$	$d_1 s_2 n$	$d_2 s_1$	$d_2 s_2$	$d_2 s_1 n$	$d_2 s_2 n$	$d_3 s_1$	$d_3 s_2$	$d_3 s_1 n$	$d_3 s_2 7n$
Stems	26·4	31·5	27·8	30·4	25·6	26·4	27·4	29·2	19·1	22·9	24·1	23·7
Leaves	13·1	15·8	16·7	18·4	14·6	15·6	16·3	21·7	15·1	20·7	20·9	25·1
Dead leaves . . .	38·7	28·5	30·9	22·8	38·4	31·1	30·1	22·5	37·4	25·4	28·2	19·8
Bolls	21·7	24·1	24·6	28·3	21·3	26·8	26·2	26·5	28·4	30·9	26·8	31·5

TABLE XII

Interaction : nitrogen and spacing

(*a*) Height (cm.)			(*b*) Internodal length (cm.)			(*c*) Dry weight per plant (gm.)			(*d*) Dry wt. per sq. yard (gm.)		
	s_1	s_2		s_1	s_2		s_1	s_2		s_1	s_2
o . . .	66·9	78·4	o . .	2·14	2·33	o . .	102	176	o . .	306	253
n . . .	82·7	88·1	n . .	2·43	2·44	n . .	179	258	n . .	538	372
	**	**		**	**		**	**		**	**
Diff. ±1·87 .	+15·8	+9·7	Diff. ±0·044	+0·29	+0·11	Diff. ±9·04	+77	+82	Diff. ±23·3	+232	+191

It is apparent that nitrogen acts as a limiting factor in case of close spacing since minium values for all growth measurements per plant are obtained under this treatment in the absence of nitrogen, and wide spacing or nitrogen stimulates elongation as well as the incorporation of dry matter. Of the two factors, 50 lb. N per acre seems to be more effective. There are further increases in height and dry matter when nitrogen is applied to widely-spaced plants. But, before considering the magnitude of such increases, it is necessary to bear in mind that s_2 plots contain less plants per unit area in comparison to those of s_1. As manure is applied at a uniform rate in lb. per acre the individual plant under wide spacing gets proportionately larger dose of manure as compared with an individual of close spacing. In spite of this privilege, widely-spaced plants derive only as much benefit in the production of dry matter from nitrogen application as the closely-spaced plants (Table XII-c). The effect is even more pronounced in case of height and internodal length where s_2 plants have distinctly responded less than the s_1 plants. There is thus a clear indication of diminished utility of nitrogen with wide spacing. This is further confirmed when the data for dry weight are considered on area basis (Table XII-d). The spacing (i.e., s^1) which produces greater dry matter in the absence of nitrogen is the most responsive to its application.

Essentially the same relations are seen to hold in case of yield and the yield characters (Table XIII). Although nitrogen affects bearing, boll development and yield significantly under either of the two spacings, the magnitude of response is distinctly heavier with the close spacing.

TABLE XIII

Interaction : nitrogen and spacing

Flowers per sq. yd.				Bolls per sq. yd.				Boll weight (gm.)				Yield (md. per acre)			
	s_1	s_2	Diff. ±9·99		s_1	s_2	Diff. ±2·81		s_1	s_2 ÷	Diff. +0·065		s_1	s_2 ÷	Diff. +0.694
o .	168	149	—19	*o* .	45·4	40·7	—4·7	*o* .	1·29	1·40	+0·11	*o* .	7·68	8·22	+0·54
n .	266	213	—53	*n* .	64·2	56·4	—7·8	*n* .	1·67	1·56	—0·11	*n* .	14·95	12·95	—2·01
Diff. ±9·99	** *+99*	** *+64*	...	Diff. ±2·81	** *+18·8*	** *+15·7*	...	Diff. ±0·065	** *+0·38*	* *+0·16*	...	Diff. ±0·694	** *+7·27*	** *+4·73*	...

The analysis can be carried a step further (Table XIV). The importnce of close spacing for the enhanced utilization of nitrogen in regard to the yield and the boll number is not general but is restricted to the two later sowings. This signifies the second order interaction D×S×N. Similar interaction effect is absent in the case of boll weight, for the effect of nitrogen is more pronounced under close than that under the wide spacing, irrespective of the sowing date.

TABLE XIV

Interrelation of dates, nitrogen and spacing

(*a*) Boll number				(*b*) Yield (md. per acre)				(*c*) Boll weight (gm.)			
	d_1	d_2	d_3		d_1	d_2	d_3		d_1	d_2	d_3
s_1 . . .	49·6	42·3	44·3	s_1 . . .	7·19	7·68	8·17	s_1 . . .	1·078	1·304	1·506
s_1n . . .	*62·9*	*67·5*	*62·2*	s_1n . .	*15·24*	*16·73*	*12·90*	s_1n . .	*1·662*	*1·737*	*1·627*
Diff. . . .	13·3	25·2	17·9	Diff.	8·05	9·05	4·73	Diff.	0·584	0·433	0·121
s_2 . . .	41·6	44·9	35·5	s_2 . . .	7·31	9·47	7·87	s_2 . . .	1·173	1·445	1·590
s_2n . . .	*66·3*	*63·1*	*39·7*	s_2d . .	*14·95*	*14·17*	*9·72*	s_2n . .	*1·549*	*1·574*	*1·569*
Diff. . . .	24·7	18·2	4·2	Diff.	7·64	4·70	1·85	Diff.	0·376	0·129	—0·071

It is clear from the data in Table XIV that the principle of fluctuating optimum finds its application to the problem of crop production. The results have, therefore, direct practical value. The adjustment in cultural conditions can safely be put forward on the basis of these results.

For want of space it is not proposed to give here even a concise account of the entire progressive growth data collected. It would be of interest all the same to consider the rate of flower production as affected by sowing date and nitrogen (Table XV).

Rates of flower production. Whereas the sowings were done at intervals of 20 days, the first flowering counts in the successive sowings were started with a delay of only half the period. In

TABLE XV

Rates of flowering per square yard (5-day totals)

Treatments	August		September						October				
	26-30	31-4	5-9	10-14	15-19	20-24	25-29	30-4	5-9	10-14	15-19	20-24	25-29
d_1	2·8	8·9	19·7	29·7	32·0	*35·8*	30·6	26·5	14·2	7·2	2·7	0·6	...
d_2	...	...	6·8	15·0	23·0	30·6	*31·2*	24·5	13·3	5·4	2·2	0·6	0·3
d_3	...	...	...	...	8·9	15·4	19·7	*25·2*	17·9	13·0	6·6	2·4	0·9
d_1n	3·9	7·4	19·2	35·1	40·9	51·2	*52·2*	50·5	31·9	16·5	3·1	0·6	...
d_2n	...	...	7·2	17·1	25·3	39·3	42·4	*51·7*	36·9	22·5	7·9	2·1	0·6
d_3n	...	...	...	...	7·4	14·5	20·1	*28·2*	26·6	25·6	16·8	7·2	5·8

fact there is a clear indication that flower counts in the two later sowings should have been started even earlier. It is the most significant point that flowering proceeds in the three sowings in quick succession both in the presence and the absence of nitrogen Furthermore, an initial postponement in sowing by 20 days causes a 5-day shift in the period of maximum flower production. The flowering in the two sowings ceases simultaneously. It is, however, true that 20 days' delay in sowing effects a substantial reduction in total bearing. This is so because the rate in the second sowing in comparison to the first remains at a low level throughout September and the difference is not made good later. When sowing is deferred by a further period of 20 days, the commencement of flowering is further shifted by about 10 days as compared with the central sowing. The peak and the cessation of flower production are also delayed but only by five days or so. The flower production during September continues at so low a rate in the last sowing that a less rapid fall in the fruiting activity during October does not compensate for the early diminution in the flowers. In short, late sowing does not mean equivalent delay in the onset of flowers and the maturity of bolls, as is commonly apprehended, but it does bring about reduction in bearing.

The effect of nitrogen on flower production is outstanding in all the sowings but it is apparent that the increases due to nitrogen in the first two sowings are recorded from 10 September and are continued to the end. On the other hand, the increase is confined to the month of October in the third sowing. This is why the response to nitrogen on bearing is comparatively low in the third sowing.

DISCUSSION

A delay in sowing by a given period shifts forth the commencement of flowering by 1/3 the interval between sowings, and the time of maximum flowering is still less affected. Thus all sowings do not enjoy equal period to grow vegetatively, before they come into bearing. The plant passes on to the reproductive phase as soon as the day length is shorter than the critical photoperiod, irrespective of the amount of vegetative growth it has made. As the appearance of flowers brings about the retardation and the ultimate cessation of vegetative activity the plants are incapacitated during fruiting to make good any loss in dry weight or the number of the nodes. Since the number of flowers are dependent on the growth already made by the plant, potential bearing suffers in the later sowing in proportion to the reduction in the vegetative growth.

Although the fall in the potential crop of flowers by deferred sowings is linear as a result of the reduction in dry weight, there are a set of counterbalancing tendencies working in the plant, which tend to keep up their yields. Any delay in sowing is accompanied by a simultaneous increase in the percentage success of flowers into bolls. In consequence thereof, the number of bolls finally matured in the second sowing equals that of the first. Of course the compensation in the last sowing, is inadequate to annul the disadvantage of reduced bearing even though the setting percentage is the maximum in this sowing.

There is a progressive increase in the weight of seed cotton produced per boll as cotton is sown successively later. The object of ameliorating *tirak* on light sandy soils is realized by delay in sowing, as boll weight is a composite measure of all round development of both seed and lint.

The cumulative effect of the above-mentioned characters, i.e. higher setting percentage and better boll weight, which offsets the reduction in flowers in the later sowing appears in the final yield of *kapas*. The efficiency of the plant as a producer of seed cotton per unit of dry matter gradually increases so that sowing date has an

optimal value around the central sowing. Besides, the third sowing excels the first by a small margin in the absence of nitrogen.

The ameliorative effect of late sowing on the opening of bolls on light sandy soils operates through the maintenance of adequate concentration of nitrogen within the plant (Table XVI) by cutting down the vegetative growth. Direct applications of nitrogen have likewise increased the percentage of nitrogen in the leaves at each stage of growth in the first sowing and correspondingly the boll size. Both these factors, late sowing and nitrogen manuring have independently increased the concentration of nitrogen as well as the size of the bolls. But the two factors, working in the same direction when combined do not contribute their individual shares in raising the boll size even though their effects on the concentration of nitrogen are additive. It is remarkable that higher concentrations of nitrogen in the late-sown treated plants are not accompanied by any additional improvement in boll size which remains at about 1·6 gm. seed cotton per boll so that sowing date and nitrogen interact in case of boll weight. The inprovement in boll opening due to nitrogen falls progressively and proportionately with advancing sowing dates. The interaction is again reflected in yield in

TABLE XVI

Concentration of total nitrogen in the leaves. Percentage on dry weight (5-plant samples)

Control					50 lb. N applied on 14-8-39				
—	Dates of sampling				—	Dates of sampling			
Sowing dates	21/8	10/9	30/9	20/10	Sowing dates—	21/8	10/9	30/9	20/10
12-5-39 . . .	2·14	1·63	1·50	1·31	12-5-39 . . .	2·47	2·84	2·12	1·76
2-6-39 . . .	2·20	1·73	1·60	1·32	2-6-39 . .	2·67	3·04	2·52	2·11
22-6-39 . . .	2·98	2·39	1·97	1·81	22-6-39 . .	3·53	3·33	3·32	2·70

the form of diminishing responses to nitrogen with delayed sowings. The differential behaviour of nitrogen with the three sowings is also recorded in case of dry weight.

The interaction between gowing date and nitrogen is explicable in terms of the progressive changes in the concentration of nitrogen in leaves of the different treatments. Nitrogen applied to the first sowing is fully utilized and finds expression in increased growth of the vegetative and the reproductive parts. There is a clear evidence of luxury consumption in the late-sown treated plants which get only inadequately depleted in comparison to all the other series (Table XVI). The higher concentrations of nitrogen which are without effect result from the combined action of the two treatments analogous in their behaviour, and point to the operation of some limiting factor. It is suggested on the basis of the growth made by plants in the three sowings prior to flowering that carbohydrates become limiting in the late sowings. A balance between carbohydrates and nitrogen appears to be of fundamental importance for the proper maturation of bolls. In early sowing there is no shortage of carbohydrate supplies. This is to be expected under conditions of long cloudless days in the summer, which enable the early-sown plant to manufacture and store large reserves of carbohydrates. In fact there is conclusive evidence [Daster, 1939] that unless utilized, the primary products of photosynthesis accumulate as starch and finally appear as tanninlike substances, on N-deficient soils. Such a condition is corrected either by delaying the sowing date or by addition of nitrogen. The mode of its action has already been explained. However, when nitrogen is applied to the late sowing the scales turn over. Only a small proportion of nitrogen is made use of in the formation of bolls while the rest raises the internal concentration and remains without further effect. It is probable that harmful effects of nitrogen concentrations might set in beyond certain limits under such conditions of unbalanced nutrition.

Gregory *et al.* [1932] obtained similar interaction of sowing date with nitrogen in yield, and linked this behaviour to the prevalence of certain external factors, (1) the rate of nitrification in the soil, and (2) the effect of climatic conditions on the nitrogen uptake by the plants. The present investigation reveals that the explanation should account for the actual utilization of the absorbed nitrogen rather than the rate of its availability and uptake.

Another important finding of the experiment is the enhanced utilization of nitrogen with closer spacing. The differential behaviour of nitrogen with spacing is well pronounced on the vegetative as well as the reproductive characters. The relation between spacing and nitrogen is in accord

with observations made by Crowther *et al.* [1937]. The ultimate source of this interaction in case of yield is the boll weight component in the present case. Thus close spacing has functioned in the same manner as the early sowing in relation to nitrogen and this behaviour becomes intelligible in terms of the explanation offered for the interaction sowing date × nitrogen. In addition, the probability that widely spaced plants are less efficient in the adequate removal of nitrogen supplied, because of their less extensive root system, cannot be set aside.

Spacing has also interacted with sowing date. For the first two sowing it is immaterial whether spacing is close or wide within the limits tried but close spacing becomes indispensable for the last sowing for counteracting the depression in boll number.

The response to water is low. Moreover it has not interacted with any other factor. This is striking in view of the hot and dry weather during 1939 under which the experiment was conducted, not in keeping with the experience of Gregory *et al.* [1932]. It follows, therefore, that water does not normally become limiting on light sandy soils. The significance of this factor and the decline in its response under late sowing has been stressed on sandy loam soils with salinity in the subsoil [Dastur and Mukhtar Singh, 1942].

Factors	*Sowing date*
Levels	d_1 = 15/5 d_2 = 31/5 d_3 = 20/6

in 6 nine-plot blocks with subplot arrangement for two spacing types (close, normal). Inspite of the fact, the level of yields in this experiment was double that of the one already discussed, owing to the favourable soil and weather conditions, there was remarkable similarity in the trends of the treatment effects of the two experiments. The yield results are condensed in Table XVII.

Further experiments

The main findings on the effect of nitrogenal sowing date, spacing and watering on the growth and yield of 4F cotton and on the interrelations of these factors have been confirmed by subsequent experiments in which other commonly cultivated varieties of American cotton were included. These experiments were carried out on light sandy soils deficient in nitrogen during the years 1940-42. The observational data included height, dry weight, boll counts, boll weights and yields. It would take much space to give the detailed results of these experiment and it is also considered unnecessary to do as they only confirm the above findings with some additional information. It would be enough, to economise space, to make a brief reference here to a $3^3 \times 2$ experiment conducted during 1941-42 in the same square of land as the 1939-40 experiment. The treatments comprised all combinations of:

Varicety	*Nitrogen*
v_1 = 4F v_2 = L. S. S. v_3 = 289F/43	o = control ne = 50 lb. N before sowing nl = 50 lb. N on 31/8

TABLE XVII

Important interaction in 1941-42 experiment

Sowing date and nitrogen

	d_1	d_2	d_3
o . . .	16·65	17·77	16·26
ne . . .	22·78	23·16	20·80
nl . . .	23·54 **	22·82 **	20·06 **
$ne—o$ . . .	6·13 **	5·40 **	4·54 **
$nl—o$ . . .	6·89	5·05	3·79
	S. Ed ±0·803		

Spacing and nitrogen for d_3

	s_1	s_2	Diff. ±0·777
o . .	17·07	15·46	—1·61 *
ne . .	21·99	19·61	—2·38 **
nl . .	22·91 **	17·90 **	—4·31
$ne—o$.	4·92 **	4·15 *	...
$nl—o$.	5·14	2·44	...
	S. Ed ±1·145		

Variety and nitrogen

	v_1	v_2	v_3
o . .	16·81	19·38	14·49
ne . .	20·99	25·14	20·61
nl . .	22·09 **	24·94 **	19·38 **
$ne—o$.	4·18 **	5·76 **	6·12 **
$nl—o$.	5·28	5·56	4·89
	S. Ed ±0·803		

Sowing date and spacing

Spacing . .	d_1	d_2	d_3
s_1 . . .	20·48	21·48	20·42
s_2 . . .	21·49 *	21·06	17·66 **
Diff. ±0·449 .	1·01	—0·42	—2·76

Differential responses to spacing (s_2—s_1)

Variety . .	d_1	d_2	d_3
4F . .	1·84 *	—1·67 *	—2·43 **
L. S. S. . .	...	1·30	—1·61 *
289F/43 . .	1·20	—1·03	—4·25 **
			S. Ed ±0·777

The decline in the response to nitrogen as sowings are delayed has been steeper with the August application as compared with the early manuring. There is an indication that early sowing should preferably be manured near flowering while the response in case if later sowings can be improved to some extent if application is made before sowing or if closer spacing is adopted. The results are again in favour of close spacing for the later sowings. The effectiveness of close spacing for late sowing is, however, particularly marked in case of the erect growing type 289F/43 or midiumly spreading variety 4F. The varieties do not appear to differ very widely in their response to nitrogen.

Summary

The investigation describes the results of factorial experiments with Punjab-American cottons on light sandy soil at the Lyallpur Agricultural Farm. The interrelations of four factors, viz. sowing date, nitrogen, water supply, and spacing have been studied, and the effectiveness of late sowings as an alternative ameliorative measure for *tirak* has been explored.

Delay in the sowing of cotton by a given period does not cause an equivalent delay in the reproductive phase. The commencement of flowering is shifted forth only by about 1/3 the interval between sowings. The peak and the cessation of flowering are still less affected. The plant exhibits photoperiodism. As flowering retards the vegetative activity of the plant, less and less period is at the disposal of the successive sowings for the production of dry matter which, therefore, falls in proportion to the delay in sowing. The meristematic activity, as given by the number of nodes and flowers, falls off progressively according as the dry weight is reduced in the later sowings.

There is a steady increase in the setting percentage as well as boll weight with delay in sowing. These counterbalancing tendencies raise the yield status of later sowings under unmanured conditions.

Nitrogen application as well as late sowing individually increase the N-concentration and correspondingly the boll weight. The two factors, therefore, are analogous in their effect.

The plant growth under the different sowings is differently affected when nitrogen is applied. The beneficial effects of nitrogen on the dry weight, the weight of seed cotton per boll and the yield diminish as sowing is deferred. Similarly increase in boll number with nitrogen application is not as high in the third sowing as in the first two sowings.

There is luxury consumption of nitrogen in the late-sown nitrogen treated plants. The high concentrations of nitrogen under these conditions get only incompletely depleted, as this surplus is neither utilized for boll development nor it takes part in growth.

Widely-spaced plants grow taller and produce greater dry matter in comparison to the individuals under close spacing. On area basis, the compensatory growth is incomplete in any of the three sowings. Boll number and yield under wide spacing are, however , made up in the first two sowings, but the compensation is inadequate in the last sowing. The last should therefore, be spaced close.

Close spacing is more efficient in the removal and the utilization of nitrogen as compared with the wide spacing (specially in the later sowing). This effect is well pronounced on vegetative and also the reproductive development.

Mean response to water is small and general. It has shown no interaction with any other factor.

Acknowledgement

Most grateful thanks of the authors are due to H. R. Stewart, Esqr., Director of Agriculture, Punjab, for his encouragement and keen interest in the work reported in this paper, and to S. S. Labh Singh, Deputy Director of Agriculture, Lyallpur, for providing necessary farming facilities.

REFERENCES

Crowther, F.,Tomforde, A., and Mahmoud, A. (1937). Manuring of cotton in Egypt. *Bull. No. 32, Royal Agricultural Society, Egypt*

Dastur, R. H. (1939). Studies in the periodic partial failures of the Punjab-American cottons in the Punjab, I. Early breakdown of the photosynthetic apparatus, II. Formation and accumulation of tannins in leaves. *Indian J. agric. Sci.* **9**, 285

——————— and Mukhtar Singh (1942). Studies in the periodic partial failures of the Punjab-American cottons in the Punjab, VII. Amelioration of *tirak* on soils with saline subsoil (sandy loams). *Indian J. agric. Sci.* **12**,679

——————————————— (1943). Studies in the periodic partial failures of the Punjab-American cottons in the Punjab, IX. The interrelation of manurial factors and water supply on the growth and yield of 4F cotton on light sandy soils. *Indian J. agric. Sci.* **13**

Gregory, F. G., Crowther, F. and Lambert, A. R. (1932). The interrelation of factors controlling the production of cotton under irrigation in the Sudan. *J. agric. Sci.* **22**,617

Lambert, A. R. and Crowther, F. (1935). Further experiments on the interrelation of factors controlling the production of cotton under irrigation in the Sudan. *Emp. J. Exp. Agric.* **3**, 276

Yates, F. (1937). The design and analysis of factorial experiments. *Imp. Bureau of Soil Sci. Tech. Communication No. 35*

CYTOLOGICAL INVESTIGATIONS ON AUTO- AND ALLO-TETRAPLOID ASIATIC COTTONS

By N. K. Iyengar, Agricultural Research Station, Surat

(Received for publication on 25 June 1943)
(With 23 text-figures)

The earliest cytological report on the behaviour of autopolyploids in cotton is that of Skovsted [1933] wherein he has described the meiosis of a triploid Asiatic cotton, which originated from a cross between the F1 of *G. herbaceum* L (H3) and *G. arboreum* L var rubicunda (Watt) designated as N 8-2 and a multiple recessive strain extracted from a cross between two closely related *G. arboreum* varieties. According to him, probably a thirteen chromosome egg had either been doubly fertilized or more probably fertilized by an accidental diploid pollen grain. In 1940, two more papers appeared on the cytology of autopolyploids which were obtained by colchicine treatment. Nakatomi [1940] described the meiosis of an Asiatic autotetraploid cotton, but the original of his work was not available to the author of the present paper owing to the present international situation. The other paper is that of Mendes [1940], describing the meiosis of an octoploid *G. hirsutum* L. As the present paper was being prepared by the author, Beasley's [1942] and Stephens' [1942] papers on the meiosis of polyploids were available. The former has described the meiosis of an autotetraploids *G. herbaceum* L and the latter the meiosis of an autotetraploid *G. arboreum* Var *neglectum* Watt. The object of the present paper is to present a cytological account of the tetraploid cottons obtained by doubling the chromosome numbers of *G. herbaceum* L, *G. arboreum* L and of the F1 hybrids between the above two species. A short account of the meiosis of an F1 hybrid plant between an Asiatic autotetraploid and a cultivated American cotton with 52 chromosomes is also given.

Material and methods

At the Agricultural Research Station, Surat, a number of cultivated Asiatic cottons were treated with colchicine during the seasons 1939-40 and 1940-41 and were maintained as ratoons during the seasons 1941-42 and 1942-43. The method of treating the plants with colchicine and the morphological accounts of the tetraploids obtained have been described by Amin [1940 ; 1941]. The following tetraploids were investigated cytologically during the season 1941-42.

(1) *G. herbaceum* L var frutescens-Delile . . . . . Strain Surat-1027 A. L. F.
(2) Ditto . Strain 1 A.-Long boll
(3) *G. arboreum* L var typicum forma bengalensis . . (H & G)-Red arboreum
(4) *G. arboreum* L var neglectum Watt, forma indica . . (H & G) strain Gaorani 6
(5) *G. herbaceum* × *G. arboreum* F1 (1027 × G. 6)
(6) Ditto × Ditto F1 (1027 × Red arboreum)
(7) Ditto × Ditto F1 (1 A. L. B. × Red arboreum)

Tetraploids 1 to 4 are considered as true autotetraploids since they are obtained by doubling the chromosomes of pure diploid species. They have four sets of identical genoms and are designated as 4 A1 or 4 A2 [Beasley 1940 ; 1942] where A1 and A2 indicate an *herbaceum* and an *arboreum* genom respectively. Tetraploids 5 to 7 are allo-tetraploids and their chromosome formula may be designated as 2 (A1 A2).

In the tetraploids under study no root tips were available for somatic counts. Tetraploidy of the plants was established solely by meiotic counts. Flower buds were collected between 10 A.M. and 12 noon and fixed either in acetic—alcohol (1 : 3) or Carnoy. These were stained with iron-acetocarmine and temporarily sealed for examination. Flower buds were also sectioned by the usual paraffin method and stained with gentian violet. For the examination of somatic chromosome numbers of the progeny of the polyploids under study, root tips were fixed in ' Craf ' and stained with crystal violet. Drawings were made with the aid of a Camera lucida, at bench level, using a 1·8 achromatic objective and X15 and X20 compensating oculars.

Fertility of the tetraploids

The autotetraploids under study did not set any bolls either by selfing or by open pollination. They, however, cross with the cultivated American cottons. The allotetraploids were found to be partly fertile either by open pollination or by selfing. Stephens [1942], however, finds some fertility in his autotetraploids either by selfing or by open pollination.

Meiosis in the tetraploid Asiatic cottons

As the course of meiosis is in general, more or less alike in both the auto- and allo-tetraploids under study, description of meiosis will be confined to the *herbaceum* (1027 A. L. F.) tetraploid in detail.

The pollen mother cells of the tetraploid are, in general, bigger than those of the diploid. A detailed account of early prophase is not attempted in this paper as it was found extremely difficult to make out the details reliably. At pachytene, the threads are extremely long and it is very difficult to follow the

aired chromosomes completely as they take a very ortuous course in the nucleus. The nucleolus is rominent and shows vacuoles. The attachment f some of the threads to the nucleolus is clear at our points but it is difficult to say how many chromo-omes are attached.

Figs. 1, 2*a* and 2*b* show nuclei in the late diplotene tages. In all these figures, the quadrivalent nature f some of the bodies could be made out. Trivalents nd univalents are also noticed. At late diplotene, he nucleolus is still very large and vacuolated and ome of the bodies are in contact with them. In ig. 2*b*, three bodies are attached to the nucleolus of hich one is a quadrivalent and two are bivalents. ig. 4 shows a diakinesis nucleus in the diploid 1027 A. L. F. Of the four bivalents around the nucleolus, wo are in contact with it and the other two are in a ifferent focus. Abraham [1940, 1] also figures a iplotene in an *arboreum* strain where he shows hree bodies around the nucleolus of which two are probably in contact with the nucleolus. Jacob [1941, 1, 2; 1942] using Feulgen-fast green technique, has shown, in somatic cells of Asiatic cottons, that there are two satellited chromosomes and two secondarily constricted chromosomes and at prophase of meiosis four chromosomes are attached to the nucleolus. These show that in the diploid four chromosomes and in the tetraploid eight chromosomes are attached to the nucleolus.

At diakinesis, the bodies get more condensed and become distinct (Fig. 3). Quadrivalents and trivalents could be made out at this stage clearly. The nucleolus gets considerably reduced and in some cases it is even lost. As such the relationship of the chromosomes to the nucleolus gets inconstant. The number of chromosomal bodies range from 14 to 25 (as examined from 15 nuclei) depending upon the number of multivalents, bivalents and univalents formed. Quadrivalents of various shapes are also seen in the figure.

Fig. 1

Fig. 2

Fig. 2*b*

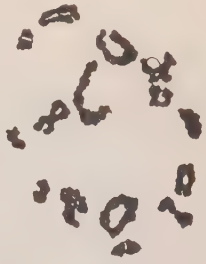

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig. 7

Fig. 8

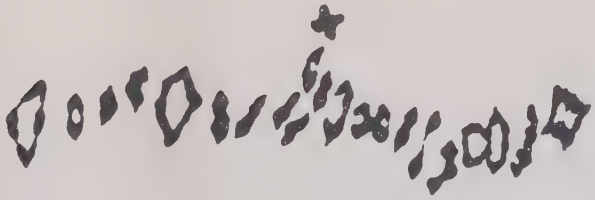

Fig. 9

Fig. 10

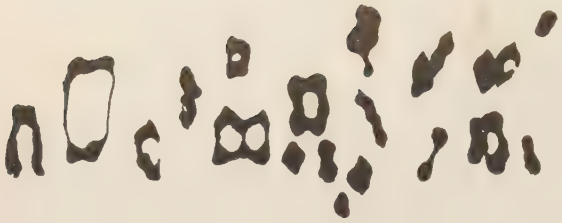

FIG. 11

FIG. 12

FIG. 13

FIG. 14

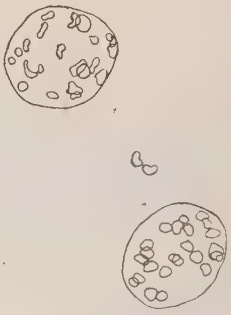

FIG. 15

FIG. 16

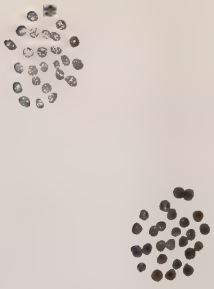

FIG. 17

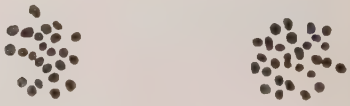

FIG. 18

FIG. 19

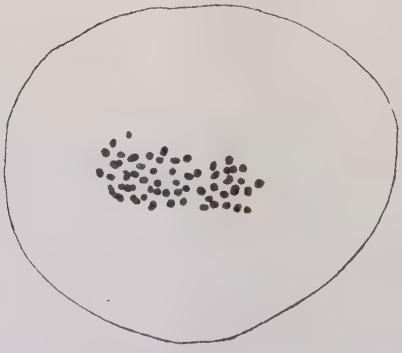

FIG. 20

FIG. 21

Fig. 22

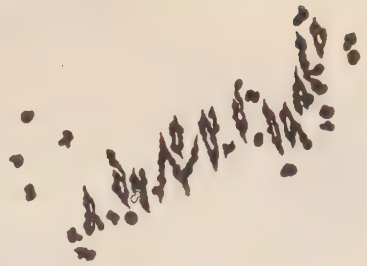

Fig. 23

Explanation of text-figures

N.B.—All figures excepting those that are specially mentioned belong to the tetraploid *G. herbaceum* (1027 A.L.F.)

Fig. 1.—Diplotene. Nuclear wall not shown . Acetocarmine smear × 792
Figs. 2*a*, 2*b*.—Diplotene drawn at two foci. Gention violet preparation × 1375
Fig. 3.—Diakinesis. (Nuclear wall not shown) showing 11 IV and 4 II. Acetocarmine smear. × 1187
Fig. 4.—Diakinesis in diploid *G. herbaceum* (1027 A. L. F.) showing 13 bivalents and a large vacuolated nucleolus. (Nuclear wall not shown) Acetocarmine smear. × 917
Figs. 5 to 11.—Gentian violet preparations showing metaphase I. × 2750
Fig. 5.—*G. herbaceum* (1027 A. L. F.) diploid showing 13 II
Fig. 6.—Tetraploid 1027 A. L. F. showing 13 quadrivalents.
Fig. 7.—*G. arboreum* (Red arboreum) tetraploid showing 2 II and 12 IV
Fig. 8.—Showing 10 IV and 6 II
Fig. 9.—Showing 6 IV and 14 II
Fig. 10.—Showing 7 IV and 12 II
Fig. 11.—Showing 8 IV+1 III+7 II+3 I
Anaphase I has already started in this nucleus. Probably the two univalent chromosomes (judging from their position) must have formed a bivalent earlier and separated precociously. Note the large ring quadrivalent beginning the anaphase.
Figs. 12 to 14.—Anaphase I. Acetocarmine smears. × 1187
Figs. 15 to 18.—Gentian violet preparations. × 1375
Fig. 15.—Interkinesis showing a univalent dividing and left in the cytoplasm. (All chromosomes not shown in the daughter nuclei).
Fig. 16.—Telophase I, showing a univalent away from the spindle
Fig. 17.—Metaphase II showing 26/26 distribution
Fig. 18.— Ditto. showing 28/24 distribution
Fig. 19.— Ditto. showing 27/25 distribution. Acetocarmine smear × 1187
Fig. 20.—Fusion of second metaphase plates. Anaphase II has already started to form a dyad. All chromosomes not drawn. Gentian violet preparation. × 1375
Fig. 21.—A bridge at metaphase II in the tetraploid (1027 × G. 6) Acetocarmine smear. × 1187
Fig. 22.—Anaphase II. Acetocarmine smear. × 1187
Fig. 23.—Mataphase I. In the F1 hybrid between *G. herbaceum* tetraploid (1 A. L. B.) and *G. hirsutum*. (Co. 2). Acetocarmine smear. × 1187

At metaphase I, the chromosomes are much more ondensed. Sometimes, the details of the quadri-alents, as has also been pointed out by Beasley 1942], are difficult to make out. The shapes of ie quadrivalents seen are single rings of four, double ngs, Vs, Ns, Ks, Xs, linear chains, etc. (Figs. to 11). The first three are much more frequent ian the others. The number of chiamsmata in ie quadrivalents varied from 3 to 5. The mean umber of chiasmata per quadrivalent was found to e 3·97 as judged from 43 quadrivalents. In the uadrivalents many of the chiasmata were found be terminalized. Sometimes subterminal chias-iata were seen. All the five types of orientations, iz. parallel discordant, convergent, linear and in-fferent were met with in the quadrivalents. In any cells the congression of the bivalents and ultivalents was so good that it was found npossible to analyse such cells.

Often, the congression was disturbed. Figs. 6 to 11 show the various types of chromosome conjugation at metaphase I. Fig. 5 shows a polar view of the diploid 1027 A. L. F. at metaphase I, showing 13 bivalents. Fig. 6 shows 13 quadrivalents in the tetraploid 1027 A. L. F., drawn at the same magnification as Fig. 5.

An analysis of mataphase I showed the range of quadrivalents from 13 to 2. Of the 93 cells examined in this material, in 50 cells full conjugation of bivalents and quadrivalents is seen. In the rest, trivalents and univalents are also seen in addition to bivalents and quadrivalents. Beasley [1942] found in his analysis of 14 cells of *G. herbaceum* tetraploid, quadrivalents ranging from 7 to 12, with an average of 10 quadrivalents per cell. Since the maximum pairing of 13 quadrivalents is met with rarely, this type of conjugation is not seen in his data. The average number of quadrivalents in the material

under study is 8·06. Such slight differences in means may be possible, as chromosome conjugation is influenced by various other factors besides chromosome homology.

Stephens' [1942] analysis of the autotetraploid *G. arboreum* is somewhat different from those of the author of the present paper and of Beasley [1942]. The origin of the autotetraploid investigated by the former is, however, different from those of the latter two. Stephens [1942] gets a mean of 6·6 quadrivalents. The mean number of bivalents is only 4·3. The univalents and trivalents are of about the same level as the materials under investigation (Table I Higher multivalents are frequently seen in Stephens [1942] data. In the present analysis they are practically absent. It is possible that such variations in higher multivalent formations may be due to variations in autosyndesis, especially so in the plants whose chromosomes are very small. Such variations in autosyndetic pairing leading to higher multivalents are also met with in the allotriploid cottons of Asiatic and cultivated American origin. The range of association in Stephens' [1942] data is from 9 to 17 in the present analysis it is from 13 to 25.

TABLE I

Mean chromosome conjugation in auto- and allo-tetraploid Asiatic cottons at metaphase I

Chromosome configurations	Autotetraploids					Allotetraploids		
	G. herbaceum L		*G. arboreum* L			*G. herbaceum* L X *G. arboreum* L		
	1027 A. L. F.	1 A. L. B.	Gaorani 6	Red arboreum	N. 14 (Stephens data-1942)	1027 × G. 6	1027 × Red-arboreum	1 A. L. B., × Red-arboreum
Univalents	0·95	0·65	0·55	0·97	0·7	1·03	0·98	1·45
Bivalents	9·04	8·89	8·25	8·35	4·3	10·50	12·59	11·55
Trivalents	0·24	0·17	0·29	2·38	0·3	0·30	0·53	0·28
Quadrivalents	8·06	8·26	8·49	8·29	6·6	7·27	6·08	6·66
Pentavalents	..	..	..	..	..	..	..	..
Hexavalents	..	..	0·02	..	0·9	..	..	..
Septavalents	..	..	..	..	..	..	..	..
Octovalents	..	..	..	..	1·0	..	..	..
Ninevalents	..	..	..	..	..	..	..	..
Decavalents	..	..	..	..	0·2	..	..	..
Total No. of p.m.c.	93	46	55	34	10	30	49	29
Mean number of association per p. m.c.	18·29 ±0·29	17·93 ±0·45	17·58 ±0·42	18·00 ±0·46	14·0 ±0·80	19·07 ±0·57	20·16 ±0·56	19·97 ±0·61
G. mean of associations per p.m.c.			17·9±0·20			19·8±0·13		

Differences within auto-and allo-tetraploids not significant. Differences between Auto- and Allo-tetraploid compared as two groups significant.

Table I also shows the mean chromosome conjugation and association in the other autotetraploids and the allotetraploids under investigation. In all the autotetraploids the mean number of quadrivalents is about the same (about 8). In the allotetraploids, though we get the same range of quadrivalents as in the autotetraploids, the mean number of quadrivalents is slightly reduced. Since in the diploid hybrid between *herbaceum* and *arboreum*, there is a reduction in the chiasma frequency at metaphase I, as compared with the pure species [Skovsted 1933; Webber 1939], it is possible to expect also a reduction in chiasma frequency in the allotetraploids and a consequent formation of less number of quadrivalents as compared with the autotetraploids.

Anaphase I and telophase I are mostly regular. The univalents either pass to one of the poles or sometimes divide and the divided halves pass to the two poles. Of the 62 nuclei examined only in four cases lagging chromosomes were noticed. Figs. 15 and 16 show such laggards at interkinesis and telophase I respectively. Such cases where anaphases are clean without any lagging univa

nts are reported in other autotetraploids where high number of quadrivalents are formed, as in traploids of *Primula sinensis* [Darlington, 1931], *icer* [Ramanujam and Joshi, 1941], *Carex sideros-cta* [Tanaka, 1940], etc. The distribution of romosomes at anaphase I is given in Table II.

TABLE II

Investigator	Chromosome distribution at anaphase I				
	26/26	25/27	24/28	23/29	Total
asley [1942] . . .	11	8	2	1	22
esent data . . .	10	8	1	1	20

It is seen, that equal distribution of chromosomes much more frequent than other distributions. milar results are obtained in many autotetra-oids.

Fig. 14 shows an anaphase I, in the autotetra-oid 1027 A. L. F., with 27 chromosomes in one le and 25 at the other. In such cases the total mber of bodies will be 52 or may sometimes be e more or less, depending upon the behaviour the univalents. In some cases, however, the tal number of bodies was much less than 52, ggesting that the four chromosomes of the adrivalent have not all been separated by the pulsion force set up at anaphase and the chias-ata holding the chromosomes have not complete-unravelled. In Fig. 12, there are 33 bodies on e whole, of which 14 are in one pole and 19 at e other. Some of the bodies have two chromo-mes, some three, one suggest four, and some show ly single bodies. A similar behaviour is also own in Fig. 13. These suggest that in some of e quadrivalents the separation of chromosomes in a 3/1 manner and in some the distribution 2/2. In Fig. 12, where a body with four chromo-mes is seen, it is possible that a quadrivalent as passed as such to a pole. Such cases of non-sjunction where multivalents have passed as ch to the poles have been reported in the autotri-oids of rice [Ramanujam, 1937], where the ab-rmality is still greater. In *Prunus* [Darlington d Moffett, 1930] and *Ribes* [Meürman, 1928], ch abnormalities persist up to second division. the tetraploids under study, the author has also ted at metaphase II, cases where there are 20 dies in one plate and 22 at the other, suggesting at some of the bodies are composed of two or ore chromosomes and are still held by chias-ata. Cases of non-disjunction where bivalents ve passed as such to the poles have been re-rded in cotton by Feng [1935] and Webber [1939]. While the formation of quadrivalents need not e a barrier for fertility in many plants, the nature of anaphase separation of the quadrivalents leading to the formation of gametes with unbalanced chromosome numbers, is taken as an explanation for the cause of sterility by some workers. Upcott [1935] considers that the low seed production, in the tetraploid *Solanum lycopersicum*, may be explained by the observed frequency of non-disjunction from quadrivalents. Müntzing [1936], Camera [1936], Randolph [1941] and others, however, consider that mere chromosomal irregularities are insufficient to account for the sterility in many autotetraploids but other factors should also be considered. Raptopoulos [1941] considers that certain descrepancies in the correlation between the number of quadrivalents and fertility may be due to differences in the relative co-orientations of their multivalents. Under such conditions, the author of the present paper feels, that in the polyploids under study, the differences in fertility may not be wholly due to the meiotic irregularities caused by multivalent formation. Further studies are necessary to explain fully the differences in sterility between the auto- and allo-polyploids under study.

Metaphase II is normally regular in having only two plates (Figs. 17 to 19). Of the 106 nuclei examined at this stage only in 21 nuclei (19·8 per cent) one or two lagging chromosomes were seen. Stephens [1942] gets about 12·5 per cent irregularity at this stage. The lagging chromosomes were found to form their own tiny pollen grains, as was actually seen at sporad and pollen grain stages. Sometimes a metaphase with three plates was seen. In one such case, there were 18 chromosomes in one plate, 21 in the second and 13 in the third. Such plates give a hexad sporad after the divisions are complete. Sometimes, fusion of two sister metaphase plates was noticed (Fig. 20). Such cases ultimately lead to a dyad sporad after the end of the division. Sporad analysis shows dyads. Somme [1930] reports such fused second metaphase plates in the autotetraploid *Primula sinensis* and Jørgensen [1928] in the autotetraploid *Solanum nigrum*. Though many cells at metaphase II are regular, the number of chromosomes in each plate is, however, variable as shown in Table III.

TABLE III

Investigator	Chromosome distribution at metaphase II					
	26/26	25/27	24/28	23/29	22/30	Total
Present data . .	30	24	19	3	1	77
Stephens' data (1942) .	17	10	6	2	0	35

As in anaphase I the mode is at 26/26. The composition of the 26 chromosomes depends upon

the type of distribution of chromosomes at anaphase I, i.e. whether 2/2 or 3/1. When quadrivalents are formed and if 3/1 distribution of chromosomes takes place at anaphase I, the conditions required to get 26/26 distributions of chromosomes are : (1) the number of quadrivalents in a nucleus must be in an even number, and (2) there must be equal chance of 3/1 separations. Though the two daughter cells have 26 chromosomes each, the number of each kind of chromosomes triplicated will be different in each daughter nucleus.

In the allotetraploid (1027 × Gaorani 6), a long bridge was seen at metaphase II, running from one plate to the other (Fig. 21). No fragment was seen. Bridges at metaphase II have been reported by the author [Iyengar, 1942, 2] in the triploid hybrids between Asiatic and American cottons. Recently, Beasley [1942] has drawn attention on the significance of bridges in cotton, from a speciation point of view.

Anaphase II is mostly regular. Of the 52 nuclei examined at telophase II, only 6 showed lagging chromosomes (11·54 per cent). Stephens [1942] obtains a more or less similar value. Fig. 22 shows a case where there are 25 chromosomes going to each pole in one spindle and 27 to each pole in the other spindle. In this pollen mother cell, 25 chromosomes must have gone to one pole and 27 to the other at anaphase I. The resulting sporads form four spores, of which, two will have 25 chromosomes and the remaining two will have 27.

Sporads are mostly regular and are composed of four spores of equal size. An analysis of 400 sporads showed 26 per cent irregularity. Most of the abnormal sporads had 1 to 8 supernumerary microspores. Dyads, pentads and hexads were rarely seen. Stephens [1942] finds in his material, 98 per cent of the ' tetrads ' normal ; the remaining 1·2 per cent were all triads and supernumerary microspores were not found.

Table IV shows the percentage of abnormal sporads and of bad pollen in some of the tetraploids under study.

TABLE IV

Tetraploids	Percentage of abnormal sporads	Percentage of bad pollen
1027 A. L. F. . . .	26	92
1 A. Long Boll . . .	8	99
Gaorani 6 . . .	16	84
1027 × Gaorani 6 F1 . .	6	46
1 A. L. B. × Red arboreum F1.	4	79

It is seen, that though the percentage of abnormal sporads is relatively low, the percentage of bad pollen is very high in all the cases. The estimation of good and bad pollen was made from fresh flowers whose anthers were about to burs and examined between 10 and 11 A.M. Th anthers were teased and the pollen was mounted i lactic acid. A cover slip was then gently applie The good and bad pollen could be made out clearl The high percentage of bad pollen shows, that de generation is caused by factors other than mer cytological irregularities met with in the poly ploids under study. A similar behaviour has bee reported in autotetraploids of other genera whe latter stages of meisis after mataphase I are fairl regular and result in normal sporads but the pe centage of bad pollen is remarkably high.

Chromosome distribution in the progeny o allotetraploids

Somatic chromosome counts of 27 plants in th progeny of the allo-tetraploids (1027 × Gaorani 6 showed that two had 51, twenty had 52, fou had 53, and one had 54 chromosomes. Similarl in the cross [tetraploid (1027 × G. 6) × cultivate Americans], of the 32 F1 plants examined for soma tic chromosome numbers, one had 51, twenty-si had 52, and one had 52+1 fragment, two had 5 and two had 54 chromosomes. The above observa tions indicate that in the tetraploids under study gametes with 26 chromosomes seem to functio most. Stephens [1942] found that all the F1 plan between autotetraploid *G. arboreum* × diploid wil cottons, had 39 chromosomes. Further we hav reason to believe that the gametes with 26 chromo somes have two full sets of Asiatic chromosome as shown by Stephens' [1942] analysis of chromo some conjugation in the triploid hybrids mention above and by the author's analysis of chromoson conjugation in an F1 hybrid between an autotetra ploid Asiatic cotton and a cultivated America as will be seen in the following section of the pape

Meiosis in the F1 hybrid between the aut tetraploid (*G. Herbaceum* 1 A. long boll) and *G. Hirsutum* (strain Co 2)

As previously stated, the autotetraploid Asiat cottons are highly pollen sterile but the *herbaceu* autotetraploids cross with the cultivated America cottons. The resulting hybrids were found to b completely sterile. One hybrid between the aut teraploid *G. herbaceum* (1 A. L. B.) and *G. hirsutu* (strain Co 2), which had 52 chromosomes (as judge from meiosis) was examined for chromosome con jugation at metaphase I. The analysis is given i Table V.

Fig. 23 shows 18 univalents, 3 bivalents, trivalents and 1 quadrivalent. In some exception cases (not mentioned in the analysis), less than univalents were noticed. Such a behaviour possible, if pairing takes place within the chrom somes of D set or one of D set pairs with th chromosomes of A set. Univalents less than

TABLE V

Chromosome configurations					Number of P. M. Cells
Univalents	Bivalents	Trivalents	Quadrivalents	Pentavalents	
13	9	7	...	...	4
13	7	7	1	...	1
13	6	6	1	1	1
13	8	6	...	1	1
13	6	9	...	...	1
14	8	6	1	...	1
14	7	8	...	...	1
14	1	12	...	...	1
15	4	8	...	1	1
15	8	7	...	...	1
16	4	8	1	...	1
16	9	6	...	...	1
18	3	8	1	...	1
Total . 226	107	119	5	3	16
Mean . 14·13	6·69	7·44	0·31	0·19	

ire reported in the hybrids between the Asiatic and cultivated American cottons [Webber, 1939 ; Beasley, 1942]. According to Skovsted [1937], in the F1 hybrid between *G. arboreum* and *G. triobum*, there is both auto- and allo-syndetic pairing. The chromosomes conjugation in one such abnormal cell, in the hybrid under study, was found to be 11 univalents, 3 bivalents, 6 trivalents 3 quadrivalents and 1 pentavalent.

At anaphase I, lagging chromosomes and bridges were noticed. Metaphase II also showed irregularities. The resulting sporads showed abnormalities. Dyads and triads were frequently noticed.

The constitution of the hybrid under study is similar to that of Beasley's [1942] hybrid between the autotetraploid *G. herbaceum* and *G. hirsutum*. His drawings of a first metaphase shows many trivalents. He concludes that the chromosome composition of this type of hybrid and of Skovsted's [1934] 52 chromosome plants are essentially the same, in having 2A1 (AD) 1.

Of the 52 chromosomes in the hybrid under study, 26 are derived from the cultivated American parent and hence one A set and one D set of chromosomes are fully represented in the hybrid, on the assumption that the constitution of the American cultivated is 2 (AD). The remaining 26 chromosomes derived from the Asiatic autotetraploid parent may have several types of constitution depending upon the number of quadrivalents and the type of segregation taking place in the quadrivalents of the particular pollen mother cell from which the gametes with 26 chromosomes is derived. If the quadrivalents regularly separates in a 2/2 manner to the poles at anaphase I then the 26 chromosomes contributed by the autotetraploid will have two A sets fully represented. The constitution of the 52 chromosome hybrid obtained in the above manner will be 2A (AD). During the meiosis of such a hybrid, the range of chromosome conjugation will be 13 III+13 I to 13 II+26 I. Since there is some affinity between and within the chromosomes of A and D sets in the diploid hybrid itself, occasional quadrivalents are also to be expected. On the other hand, if the number of quadrivalents in the autotetraploid are in an even number and at anaphase I if 3/1 and 2/2 segregations take place in equal chances to the two poles, the 26 chromosome gametes, thus derived from the autotetraploid will have some chromosomes represented three times and some represented once. This replication depends upon the number of quadrivalents formed and thus the types of chromosome configurations to be expected in the hybrids will vary according to circumstances. A study of a number of hybrids is underway to see how far the above expectations are fulfilled.

DISCUSSION

Chromosome conjugation in autotetraploids

In an autotetraploid there are four sets of homologous chromosomes and in an ideal case quadrivalents corresponding to the basic set are formed, as in the tetraploids of *Datura* (Belling, 1927], *Melandrium album* [Ono, 1939] and *Gasteria* [Sato, 1939]. But such a condition does not always hold good in many plants. In the autotetraploid *Lycopersicum esulentum* with 48 somatic chromosomes we have different results. According to Jørgensen [1928] only one or two quadrivalents are formed. Lindstrom and Koos [1931] obtained mostly 12 quadrivalents and rarely bivalents. Lesley and Lesley [1930] found that seven quadrivalents are often formed but twelve quadrivalents were rarely seen. Upcott [1935] gets a range of 1-8 quadrivalents. Similar diversity of results are obtained in other autotetraploids as in *Primula sinensis* [Sömme, 1930 ; Darlington, 1931], barley [Peto, 1936 ; Von Bergh, 1936], etc. According to Darlington [1931], these differences in quadrivalent formation between the above genera are due to differences in the frequency of chiasma formation in the species. Tanaka [1940] points out that the origin of the parent diploids and the physiological influence of the cytoplasm on the formation of fiuadrivalents, should also be considered.

In some autotetraploids chromosome conjugation is further complicated by structural changes like interchange. Here, besides quadrivalents and bivalents, higher associations like penta-

hexa-, and septa-valents are also met with. Such tetraploid interchange heterozygotes have been reported by Tanaka [1940] in *Carex siderosticta*, by Müerman [1929] in *Aucuba japonica* and others. Thus, chromosome association shows wide variations in autotetraploids from genera to genera, species to species and even within the species. These indicate that besides chromosome homology, other internal and external factors should also be considered.

In the case of cotton, the chromosome morphology of the Asiatic cottons shows size differences within the somatic complement [Skovsted, 1933, 1934 ; Arutjunova, 1936 ; Abraham, 1940 ; Jacob, 1942 and as examined by the author of this paper]. These differences in the length of the chromosomes may pa tly be responsible for the reduction in the expected numbers of quadrivalents. Secondly, according to Skovsted [1933], the Asiatic cottons are themselves polyploids and though normally regular bivalents are formed in the diploids, under some conditions, as when it is in the triploid condition (1933, 1934) and in haploid condition [as in the haploid American cottons (1933), where a few trivalents are formed] there is autosyndesis within the Asiatic complement. Such a behaviour may be shown in autopolyploids under some conditions. Recently Jacob [1941, 1, 2, 3 ; 1942] has pointed out that structural changes have played a part in the evolution of the Asiatic diploid cottons. Such changes may also influence the chromosome conjugation in the autopolyploids arising from such changed diploids.

Auto- and Allo-polyploidy

Kihara and Ono [1926] classified polyploids into two groups, i.e. auto- and allo-. But the boundary between these two groups has become more and more vague, as continuous relation exists between the two groups, as shown by a number of people.

From a chromosome pairing point of view, it is generally held that autopolyploids are differentiated from the allopolyploids by the number of multivalents formed during meiosis. But there are autopolyploids which form mostly bivalents as in *Solanum nigrum*, [Jrgensen, 1928]. *Solanum gracile* [Kagawa, 1937], *Tulipa chrysantha* [Upcott, 1939], etc. Kasparyan [1934] shows amphidiploids where chromosome behaviour is the same as in autopolyploids, as well as cases where there are regular pairing as in diploids and various intermediate cases. According to him, the tendency for multivalent formation depends more on the number of chiasmata norma ly formed by the chromosomes of the initial species than on the degree of homology of the different sets in the polyploid. Vorobiev [1934] says that the truer nature of any plant, particularly whether true auto- or allopolyploid, can be decided only by combining a genetical study with the cytological study, especially in view of the growing doubt as to the validity of chromosome conjugation as a criterion of homology. Mnützing [1936] points out that even in pronounced allopolyploids there must be considerable degree of autopolyploidy as the different genoms have a great deal in common. Stebbins [1940] under certain limitations, defines an autopolyploid as a polyploid of which the corresponding diploid is a fertile species, while the allopolyploid is a polyploid containing the doubled genom of a more or less sterile hybrid.

In cotton, we have two types of allotetraploids ; one resulting from a cross between two closely related species as *herbaceum* and *arboreum* where bivalents are formed at meiosis in the diploid F1. On doubling the chromosome number of the hybrid the allopolyploid formed shows a fairly high degree of quadrivalent formation as mentioned in the body of the paper. This situation is similar to the case in *Crepis* hybrids [Poole, 1931]. The behaviour of the other type of allotetraploids in cotton which are obtained by doubling the chromosome number of the F1 hybrids between *G. arboreum* and *G. anomalum* [Iyengar, 1942] ; *G. anomalum* and *G. Davidsonii* [Iyengar, unpublished] ; *G. thurberi* and *G. arboreum* [Beasley, 1940, 2] is different. These show mostly bivalents. The diploid F1 hybrids of these polyploids show a high degree of sterility but the polyploids are relatively much more fertile.

Summary

Meiosis has been described in the autotetraploid *G. herbaceum* (1027 A. L. F.). Chromosome conjugation was studied at metaphase I, in the autotetraploids of two strains of *G. herbaceum*, of two strains of *G. arboreum* and in the allotetraploids obtained from three hybrids between the above two species. A high proportion of quadrivalents is seen in all the tetraploids. On an average the proportion of quadrivalents is slightly lower in the allotetraploids. Maximum association leading to 13 quadrivalents, is met with rarely. Meiosis, at later stages, is in general regular and finally normal sporads are mostly formed. But the pollen is largely defective, particularly so in the autotetraploids.

The autotetraploids are pollen sterile and do not cross with the cultivated Asiatic diploids, but some success was obtained when the autotetraploids were crossed on to the cultivated Americans. The allotetraploids are self fertile to a certain extent.

The progeny of the tetraploids had mostly 52 somatic chromosomes, indicating that in the tetraploids gametes with 26 chromosomes seem to function most.

Meiosis in a sterile hybrid plant (2n=52) obtained from the cross between the autotetraploid *G. herbaceum* (1 A. L. B.) and *G. hirsutum* (Co 2), showed that many of the chromosomes of the three A sets are associated as trivalents and the chromosomes of D set, left as univalents. The sterility in this hybrid may be partly due to the irregularity initiated by the formation of trivalents and univalents in large numbers, caused by the constitution AA (AD).

Acknowledgements

The author is highly indebted to Mr G. B. Patel, under whose guidance this work is being done, for his valuable suggestions and discussions both during the progress of the work and finally in writing up the paper. My thanks are due to Mr K. C. Amin for supplying me with the several pieces of information on the polyploids under study. Thanks are also due to Dr B. S. Kadam, for allowing the author to make use of his library for references.

The investigation was carried out as a part of the Inter-Specific Hybridization Scheme for Cottons, financed by the Indian Central Cotton Committee.

References

Abraham, P. (1940, 1.) Cytological studies in *Gossypium* I. chromosome behaviour in the interspecific hybrid *G. arboreum* × *G. Stocksii*. *Indian J. agric. Sci.* **10**, 285-9

———— (1940, 2). Morphology of the somatic chromosomes of three Asiatic cottons. *Indian J. agric. Sci.* **10**, 299-302

Amin, K. C. (1940). A preliminary note on interspecific hybridization and use of colchicine in cotton. *Curr. Sci.* **9**, 74-5

———— (1941, 1). Interspecific hybridization and colchicine induced polyploidy in cotton. *I. C. C. C. Second Conf. Sci. Res. Workers on Cotton in India, Paper* **5**

———— (1941, 2). Interspecific hybridization and colchicine induced polyploidy in cotton. *I. C. C. C. Second Conf. on Cotton Growing Problems in India, Report and Proceedings*, 39-42

Arutjunova, L. G. (1936). An investigation of chromosome morphology in the genus *Gossypium C. R.* (*Doklady*). *Acad. Sci. U. R. S. S.* **12**, 37-40 (original not seen)

Beasley, J. O. (1940). The production of polyploids in *Gossypium*. *J. Hered.* **31**, 39-48

———— (1942). Meiotic chromosome behaviour in species, species hybrids, haploids and induced polyploids of *Gossypium*. *Genetics* **27**, 177-205

Belling, J. (1927). The attachments of chromosomes at the reduction division in flowering plants. *J. Genet.* **18**, 177-205

Bergh von, K. H. (1936). Autotetraploidie bei *Hordeum bulbosum* L Der Zuchter **8**, 152-8

Camera De Souza, Da, A. (1936). Elementos para o estudo da inducao de poliploides no trigo. *Anna Inst. Sup. Agron. Lisboa.* **7**, 214-33 (original not seen) *Pl. Breeding Abs.* **7**, 173

Darlington, C. D. (1931). Meiosis in the diploid and tetraploid *Primula sinensis*. *J. Genet.* **24**, 65-96

———— (1937). *Recent Advances in Cytology.* (J. & A. Churcill, Ltd.), London, 2nd Ed.

Darlington, C. D. and Moffett, A. A. (1930). Primary and secondary chromosome balance in *Pyrus*. *J. Genet.* **22**, 129-51

Feng, C. F. (1935). Genetical and cytological study of species hybrids of Asiatic and American cottons. *Bot. Gaz.* **96**, 485-504

Iyengar, N. K. (1942, 1). A note on a synthetic tetraploid in Asiatic cotton. *Madras Agric. J.* **30**, 49-52

————(1942, 2). Chromatin bridges in cotton. *Indian J. agric. Sci.* **12**, 785-7

Jacob, K. T. (1941, 1). Preliminary observations on the chromosome morphology in Asiatic cottons with special reference to their phylogeny and interrelationships *I. C. C. C. Second Conf. of Sci. Res. Workers in India, Paper* **6**

———— (1941, 2). *I. C. C. C. Second Conf. on Cotton Growing Problems in India. Report and Proceedings*, 42-5

———— (1941, 3). Certain abnormalities in the root tips of cotton. *Curr. Sci.* **10**, 174

———— (1942). Studies in cotton IV. Morphology of the somatic chromosomes in eight types of Asiatic cottons. *Trans. of the Bose Res. Inst.* **15**, 17-27

Jørgensen, C. A. (1928). The experimental formation of heteroploid plants in the genus *Solanum*. *J. Genet* **19**, 133-211

Kagawa, F. (1937). Chromosomal chimeras and polyploidy in *Solanum gracile*, Link. *Cytologia, Fujii. Jil.* Vol. 733-74

Kasparyan, A. S. (1934). Survey of works in polyploidy and amphidiploidy during recent years. *Bull. Appl. Bot. Leningrad. Ser.* **2**, (6), 205-222

Kihara, H. and Ono, T. (1926). Chromosomen zahlen und systematische gruppierung der *Rumex*-Arten. *Zeits. F. Zellforsch. u. mikr. Anat* **4**, 475-81

Lesley, M. M. and Lesley, J. W. (1930). The mode of origin and chromosome behaviour in pollen mother cells of a tetraploid seedling tomato. *J. Genet.* **22**, 419-25

Lindstrom, E. W. and Koos, K. (1931). Cytogenetic investigations of a haploid tomato and its diploid and tetraploid progeny. *Amer. J. Bot.* **18**, 398-410

Mendes, A. J. T. (1940). Polyploid cottons obtained through use of colchicine, I. cytological observations in octoploid *Gossypium hirsutum*. *Bot. Gaz.* **102**, 287-94

Meürman, O. (1929). Association and types of chromosomes in *Aucuba japonica*. *Hereditas.* **12**, 179-209

Mützing, A. (1933). Hybrid incompatibility and the origin of polyploidy. *Hereditas.* **18**, 33-55

———— (1936). The evolutionary significance of autopolyploidy. *Hereditas*, **21**, 263-378

———— (1937). The effects of chromosomal variations in *Dactylis*. *Hereditas.* **23**, 113-235

Nakatomi, S. (1940). Induced polyploidy in Asiatic varieties of cotton plant by colchicine treatment *Proc. Crop. Sci., Japan* **12**, 16 (original not seen) *Pl Breeding. Abs.* **11**, 2

Ono, T. (1939). Polyploidy and sex determination in *Melandrium* I. Colchicine induced polyploids of *M. album*. *Bot. Mag. Tokio* **53**, 449-556

Pal, B. P. et al. (1941). Colchicine induced polyploids in crop plants, II. Chilli (*Capsicumannuum*). *Indian J. Genet. and Pl. Bred.* **1**, 28-40

Peto, F. H. (1936). Heat induced tetraplody in barley *Canad. J. Res.* **14**, 445-7

Poole, C. F. (1931). The interspecific hybrid *Crepis rubra* × *C. foetida* and some of its derivatives I. *Univ. Calif. Pub. Agr. Sci.* **6**, 169-200

Ramanujam, S. (1937). Cytogenetical studies in the *Oryzeae*, III. Cytogenetical behaviour of an interspecific hybrid in *Oryza*. *J. Genet.* **35**, 223-58

Ramanujam, S. and Joshi, A. B. (1941). Colchicine induced polyploidy in crop plants, I. Gram (*Cicar arietinum L*). *Indian J. agric. Sci.* **11**, 835-47
Randolph, L. F. (1935). Cytogenetics of tetraploid maize. *J. agric. Res.* **50**, 591-605
———— (1941). An evaluation of induced polyploidy as a method of breeding crop plants. *Amer. Nat.* **75**, 347-65
Raptopoulos, T. (1941). Chromosomes and fertility of cherries and their hybrids. *J. Genet.* **42**, 91-114
Sato, D. (1939). Karyotype alteration and phylogeny. *Bot. Mag.Tokyo.* **53**, 55-764
Skovsted, A. (1933). Cytological studies in cotton, I. The mitosis and meiosis in diploid and triploid Asiatic cottons. *Ann. Bot.* **47**, 227-51
———— (1934). Cytological studies in cotton, II. Two interspecific hybrids between Asiatic and New World cottons. *J. Genet.* **28**, 407-24
———— (1937). Cytological studies in cotton, IV. Chromosome conjugation in interspecific hybrids. *J. Genet.* **34**, 97-134
Sōmme, A. S.(1930). Genetics and cytology of the tetraploid form of *Primula sinensis*. *J. Genet.* **23**, 447-509
Stebbins, G. L. Jr. (1940). The significance of polyploidy in evolution. *Amer. Nat.* **74**, 54-66
Stephens, S. G. (1940). Colchicine treatment as a means of inducing polyploids in cotton *Trop. Agric. Trin.* **17**, 23
———— (1942). Colchicine produced polyploids in *Gossypium*, I. An autotetraploid Asiatic cotton and certain of its hybrids with wild diploid species. *J. Genet.* **44**, 272-95
Tanaka, N. (1940). Chromosome studies in cyperaceae, VIII. Meiosis in diploid and tetraploid forms of *Carex siderosticta* Hance. *Cytologia.* **11**, 282-310
Upcott, M. B. (1935). The cytology of triploid and tetraploid *Lycopersicum esculentum*. *J. Genet.* **31**, 1-19
———— (1939). The genetic structure of *Tulipa III*. *J. Genet.* **37**, 303-9
Vorobiev, A. I. (1934). Multiple chromosome numbers in related forms. *Bull. Appl. Bot. Leningrad. Ser.* **2** (6), 37-101
Webber, J. M. (1934). Chromosome number and meitoic behaviour in *Gossypium*. *J. agric. Res.* **49**, 223-37
———— (1935). Interspecific hybridization in *Gossypium* and the meiotic behaviour of F1 plants *J. agric. Res.* **51**, 1047-70
———— (1939). Relationships in the genus *Gossypium* as indicated by cytological data. *J. agric. Res.* **58**, 237-61

STUDIES ON THE ROOT ROT OF COTTON IN SIND, I

By N. Prasad, Assistant Mycologist, Agricultural Research Station, Sakrand, Sind

(Received for publication on 12 December 1942)

Root rot is one of the more common diseases affecting cotton in India and has been recorded to be serious in the Punjab, Gujerat and Sind. This disease occurs in Sind every year and is responsible for causing considerable damage to the cotton crop in the province. Generally, the percentage of infection varies between 5 and 10 per cent but observations taken at Government Auxiliary Farm, Shahdadkote, show that the intensity of infection can be as high as 60 per cent. Vasudeva [1935], who investigated the problem at Lyallpur, found that both *Rhizoctonia solani* Kühu and *Rhizoctonia bataticola* (Taub) Butl. can cause the disease in the Punjab, while Likhite and Kulkarni [1934] are of the opinion that in Gujerat it is due to the combined effect of *Rhizoctonia bataticola* (Taub) Butl. and a nematode. The above workers obtained certain types of *Fusaria* along with *Rhizoctonia bataticola* (Taub) Rutl. in the isolations from the affected roots of cotton. Since there appears to be variation in the organism and symptoms associated with this disease, investigations were undertaken to determine the nature and the cause of this disease in Sind.

Symptoms

The first visible symptom of the disease is complete wilting of the plant. The affected plant can be pulled out easily from the soil. Practically all the lateral roots are destroyed. On squeezing the roots, a yellow liquid oozes out. The cortical tissues of the root become fibrus and the central woody portion turned brown and in severe cases of attack it becomes black.

In certain respects, the root rot of cotton in Sind resembles the root rot in the Punjab, Gujerat and Texas. The common symptoms at all these places are that the affected plants die suddenly, the roots of the plants become yellow in colour and on squeezing the roots, a yellow liquid oozes out. Peltier [1926] reports that the leaves of the plants attacked by root rot in Texas become yellow before the actual wilting starts. This symptom has not been observed either in the Punjab, Gujerat or Sind.

In Texas, the root rot is caused by *Phymatotrichum omnivorum* (Shear) Duggar. It is generally serious at the time of square formation. In Gujerat the disease appears when the flowers have been formed while in the Punjab it appears when the plants are about two months old. But in Sind the disease manifests itself when the plants are only 15 days old and continues up to the boll formation stage. Thus the disease in Sind appears much earlier and remains active for a longer period than in the Punjab or Gujerat.

Isolation

Two methods of isolation were used :

(*i*) By surface sterilization of the affected

portion in 0·1 per cent mercuric chloride solution and transferring these pieces aseptically to agar slants after washing them thoroughly in sterilized water.

(*ii*) Davies [1935] silver nitrate, sodium chloride method was used.

From almost all the pieces of infected tissue, *Fusarium*, *Rhizoctonia* and few other saprophytic fungi grew out in the course of a week. Over 700 isolations were made from different places. Saprophytic fungi like *Aspergillus*, *Penicillium*, etc. were eliminated. The rest of the isolates were grouped under seven groups. For grouping these aerial mycelium, discoloration of the medium and spore-bearing structures were taken into consideration. Afterwards these groups were microscopically examined and slight differences were found to exist between them. The characters on which these groups were based are given in Table I.

TABLE I

Types of fungi isolated from cotton

Type No.	Aerial mycelium	Discoloration of the mycelium	Spore bearing structures
1	Whitish, fluffy	Light brown	None
2	Pinkish	Pink	None
3	None	None	Sclerotia abundant
4	Scanty, whitish	Dark brown	Sclerotia abundant
5	White	Dark brown	Sclerotia not abundant
6	Dirty white	Black	Sclerotia abundant
7	Buff	Brown	None

TABLE II

Number of isolates of each type obtained

Type No.	No. of cultures of isolates on 30-1-1939 Sakrand	30-4-39 Sakrand	15-9-39 Sakrand	30-5-39 Dadu	15-6-39 Mirpur-khas	1-7-39 Sakrand	1-8-39 Sakrand	3-9-39 Shahdad-kot	Total No. isolates
1	5	11	7	6	11	7	3	22	67
2	2	3	6	0	2	8	2	7	28
3	9	7	5	0	9	9	5	25	60
4	3	2	2	5	1	11	0	6	30
5	11	5	10	7	0	13	9	10	54
6	6	8	0	0	3	2	0	11	24
7	7	0	0	0	0	3	3	13	28

In Table II are given the numbers of various types of isolates that were obtained at each isolation along with the locality from where the affected material was collected.

PATHOGENICITY TESTS

Inoculum of types 1-7 was prepared by growing these fungi in Erlenmeyer flasks on sterilized mixture of 190 gm. of soil and 10 gm. of wheat flour. To every 200 gm. of mixture 60 c.c. of water was added. Five flasks of each type were prepared. In about three weeks' time the cultures were ready to be transferred to the pots. 12 inch pots were two-thirds filled with sterilized soil. Half the contents of each flask were sprinkled over the sterilized soil. Six cotton seeds were placed on the inoculum in the pots. These seeds were covered with the other half of the inoculum which in turn was covered with sterilized soil. There were four pots of each type. In the pots kept as control, the seeds were sown between two layers of sterilized soil and wheat flour.

The seedlings emerged through the soil six days after the sowing. There was good germination in nearly all the pots. Twenty days after the sowing wilting appeared in pots inoculated with type 3. The wilting was very sudden and the plant was found in a drooping condition. In about a week's time in that series of pots practically all the plants died. Two days after the first wilting appeared, plants began to die in pots inoculated with types 1 and 5. The experiment was finished on 24 April 1939. Results obtained from this experiment are given in Table III.

The wilted plants were taken out and isolations made from them. In all the cases, the fungi obtained were the same as those they had been infected with. Some plants were found to be wilting in the control pots as well, isolations from such plants yielding fungi like *Aspergillus*.

It is clear from the above experiment that a type of *Fusarium* and two types of *Rhizoctonia* are capable of causing a disease in cotton similar to root rot in nature. By comparing the results of this experiment to the table of isolations, it is revealed that the isolates which were parasitic appeared most frequently at the time of isolations.

The symptoms produced by *Fusarium* and *Rhizoctonia* resembled each other in all essential characteristics. The main difference between the two was that the discoloration produced by *Rhizoctonia* was very much darker than was the case with *Fusarium*.

Infection experiment I

TABLE III

Germination and rotting with isolate Nos. 1 and 7

Types of isolates	No. of seedlings germinated	No. of seedlings rotted	Germination percentage	Rotting percentage
1	21	5	87·5	24·0
2	20	0	83·3	..
3	22	7	91·7	31·8
4	19	0	79·2	..
5	18	3	75·0	16·7
6	17	0	70·8	..
7	21	0	87·5	..
Control	23	0	95·8	..

EXPERIMENT II

Only isolates 1 and 3 were selected for further trial as these caused the greatest amount of damage. The inoculum was made in the usual manner. The following five series of pot culture were arranged.

(*i*) Pots having inoculum type 1 only, i.e. *Fusarium* alone.

(*ii*) Pots having $\frac{3}{4}$ inoculum from type 1 and $\frac{1}{4}$ from type 3, i.e. *Rhizoctonia*.

(*iii*) Pots having $\frac{1}{2}$ inoculum from type 1 and $\frac{1}{2}$ from type 3.

(*iv*) Pots having $\frac{1}{4}$ inoculum from type 1 and $\frac{3}{4}$ from type 3.

(*v*) Pots having inoculum from type 3, i.e. *Rhizoctonia* alone.

In the central pots the seeds were sown in between the layers of sterilized soil and wheat flour. Six seeds of cotton were sown in each pot.

The seedlings emerged through the soil six days after the sowing. The germination was good in all cases. In the pots having half and half inoculum from each type, the wilting appeared 19 days after sowing, while in other cases wilting appeared after 28 days. The results obtained in this experiment are given in Table IV.

Infection experiment II

TABLE IV

Germination and rotting with isolates 1 and 3

S. No.	Types of isolates	No. of seedlings germinated	No. of seedlings rotted	No. of days to rot	Germination percentage	Rotting percentage
1	*Fusarium* alone isolate No. 1	21	14	26	87·5	19·0
2	$\frac{1}{4}$ *Fusarium*, $\frac{3}{4}$ *Rhizoctonia*	22	6	25	91·7	27·3
3	$\frac{1}{2}$ *Fusarium*, $\frac{1}{2}$ *Rhizoctonia*	20	16	19	83·3	80·0
4	$\frac{3}{4}$ *Fusarium*, $\frac{1}{4}$ *Rhizoctonia*	19	5	27	95·8	26·3
5	*Rhizoctonia* alone	23	6	25	95·8	26·0
6	Control without any inoculation	24	0	..	100·0	..

It is quite clear from the above experiment that *Fusarium* (Type 1) and *Rhizoctonia* (Type 3) are more parasitic when together than either of them singly. When together they cause the disease to appear much earlier and the number of plants attacked is also much more.

The symptoms produced by *Rhizoctonia* and *Fusarium* in combination very much resemble that produced by *Rhizoctonia*. The discoloration of the roots is much more intense and the colour varies from dark brown to black. The discoloration is the deepest at the collar.

Morphology of the root-rot fungi

Isolates 1, 3 and 5 which caused rotting were selected for morphological study. Isolate No. 1 was a *Fusarium* while the other two belonged to the genus *Rhizoctonia*.

Both the isolates 3 and 5 were grown on oatmeal agar and potato dextrose agar along with a pure culture of *Rhizoctonia bataticola* (Taub) Butl. obtained from the Imperial Mycologist, Imperial Agricultural Research Insittute, New Delhi. They resembled each other in all essential characters. The diameter of the mycelium and of sclerotia was found to be the same in all cases. The isolate No. 5 differed from No. 3 only in the presence of a white fluffy mycelium.

Efforts were made to obtain the pycnidial stage. The fungi were grown on different media at different hydrogen-ion concentrations and at different temperatures. At no stage, pycnidia were found to appear. So the fungus has tentatively been given the name *Rhizoctonia bataticola* (Taub) Butl.

The isolate No. 1 was grown at a temperature of about 25°C. in tubes of media prepared according to the methods of Wollenweber *et al.* [1925] and its characters were noted on these media. The culture of this *Fusarium* was sent to the Imperial Mycologist, Imperial Agricultural Research Institute, New Delhi, for identification. It has been identified by him to be *Fusarium coeruleum* (Lib) Sacc. The characters of this are as follows.

Spores are in cream coloured and bluish green sporodochia, typical martiella shape with distinct septations and rounded base and oblique tip. Mostly 3-septate chlamydospores are present terminal and inter-calary. Microconidia abundant in aerial mycelium in false heads. 3-septate macro-conidia measure $5{\cdot}0 \times 27{\cdot}6$ ($4{\cdot}6$—$6{\cdot}0 \times 24{\cdot}1$—$32{\cdot}5$) μ, giving a length to breadth ratio of $5{\cdot}5 : 1$.

Discussion

The isolations carried out from the rot affected roots of cotton have always produced *Fusarium coeruleum* (Lib) Sacc. and *Rhizoctonia bataticola* (Taub) Butl. and both of them have been found to be parasitic. *Rhizoctonia solani* Kühn which causes root rot of cotton in the Punjab has been found to be entirely absent. It has not even been obtained in one out of the 700 isolations. Nematodes, which are associated with the root rot of cotton in Gujerat, have also been found absent in Sind.

This study has confirmed the findings of Likhite and Kulkarni [1934] and Vasudeva [1935] that *Rhizoctonia bataticola* (Taub) Butl. is the chief cause of root rot of cotton in India. It has further shown that *Fusarium coeruleum* (Lib) Sacc. is also one of the important causes of root rot in Sind.

In the United States of America Woodroof [1927] has reported that a damping off disease in cotton is caused by *Fusarium moniliforme* Sheld. In Sind the root rot of cotton is also known to occur in early part of June when cotton is just in the seedling stage. Perhaps this might be comparable to the damping off of cotton seedlings in U. S. A. It is difficult to say at the present stage of knowledge that *Fusarium coeruleum* (Lib) Sacc. causes this disease in Sind while *Rhizoctonia bataticola* (Taub) Butl. is responsible for root rot of cotton at a later stage. Fact at present remains that both the fungi have been isolated at all stages of growth of cotton and both have been found to produce a similar disease in artificially infected pots. Further study of this problem will be able to throw a proper light on this important issue.

Summary

Isolations were carried out from rot-affected roots of cotton collected from different places in Sind. These gave cultures of *Fusarium* and *Rhizoctonia*. Both of these were found to be parasitic. They were found to be doing much more damage when both of them were together. They were identified to be as *Fusarium coeruleum* (Lib) Sacc. and *Rhizoctonia bataticola* (Taub) Butl.

Acknowledgements

The author is very grateful to Dr G. Watts Padwick, Imperial Mycologist, for kindly identifying the culture of *Fusarium*.

References

Butler, E. J. (1918). *Fungi and diseases in plants.* Thacker spink & Co., Calcutta

Davies, F. R. (1935). *Canad. J. Res.* **13**, 168-73

Likhite, V. N. and Kulkarni, V. G. (1934). *Curr. Sci.* **3**, 252-4

Peltier, G. L., King, C. J. and Samson, R. W. (1926). *U. S. Dept. Agri. Bull. No.* 1417

Taubenhaus, J. J. and Killough, D. T. (1932). *Bull. Texas agric. Expt. Sta. No.* 307

Vasudeva, R. S. (1935). Studies on the root-rot disease of cotton in the Punjab, I. Symptons, incidence and cause of the disease. *Indian J. agric. Sci.* **5**, 496-512

Wollenweber, H. W., Sherbakoff, C. D., Reinking, O. A., Johaun, H. and Bailey, A. A. (1925). *J. agric. Res.* **30**, 833-43

Woodroof, N. C. (1927). *Phytopath.* **17**, 227-38

FURTHER STUDIES ON THE STEM-ROT DISEASE OF RICE CAUSED BY *SCLEROTIUM ORYZAE* CATT. IN THE PUNJAB

By Chetan Swarup Paracer, M.Sc. (Agri.), Demonstrator in Botany and Jai Chand Luthra, M.Sc., D.I.C. (London), I.A.S., Professor of Botany, Punjab Agricultural College and Research Institute, Lyallpur

(Received for publication on 5 August 1943)

Rice is one of the staple food grain crops of the Punjab hills. It occupies about one million acres. It is subject to a number of fungal diseases of which the Stem-rot is most serious and causes heavy damage. The loss due to this disease varies from year to year and place to place. In certain years, when the conditions are favourable for the disease, half to three-fourths of the crop is destroyed. The loss of 5 to 15 per cent of the crop is common every year. It amounts to several lakhs of rupees.

The disease occurs mostly in the Sheikhupura, Gujranwala, Karnal and Gurdaspur districts and is met with to a small extent in hills.

Some preliminary studies on this disease in the Punjab were conducted by Luthra and Sattar [1936]. They described the pathogenicity of the causal fungus (*Sclerotium oryzae* Catt.), symptoms, distribution and modes of perpetuation of the disease.

The present paper deals with the study of certain environmental factors affecting the incidence of the disease and its control measures.

Experimental

A. Material and methods

Rice seed for the experimental crop was obtained from he Assistant Cerealist, Rice Farm, Kala Shah Kaku, and was grown by two methods, viz. (i) broadcast and (ii) transplanting of seedlings.

Before use the seed was disinfected in 0·1 per cent solution of mercuric chloride for 15 min. The soil was infected by adding to the upper 3-4 in. of it diseased rice stubble or pure culture of the fungus. The fungus was grown on husked rice and oatmeal agar (oatmeal 50 gm., agar agar 20 gm., made up to one litre in distilled water) at 25°C. and three weeks old culture thus prepared was used.

Manures were added two weeks after transplanting of seedlings. Each fertilizer was mixed with an equal amount of powdered soil before adding to the plots. This was done to facilitate application.

The experimental plots for control measures were separated from each other by 3 ft. high walls of unburnt bricks to prevent the transfer of diseased material from one plot to the other. Experiments were carried out at the Botanical Farm, Lyallpur, and the Rice Farm, Kala Shah Kaku.

B. Effect of sowing and transplanting rice on different dates

The sowing and transplanting of rice in the Punjab are started in the first week of May and continue to the middle of July depending upon the variety of rice to be grown, water supply and local cultural practice.

In order to study the effect of sowing and transplanting of rice on different dates, in 1935 an uninfested piece of land was divided into small plots each measuring 25 × 3 ft. Rice No. Jhona 349 was used in the experiment. Sowing and transplanting were carried out after every fortnight. Sowing was started from 10 May and transplanting from 10 June and were continued to 25 August. For every planting forty-day-old seedlings were used. In each case soil was infected with the culture of the fungus five days before sowing and transplanting.

There were two sets of experiments. In set A, plants were thinned one month after sowing or transplanting and the other set B was not thinned. Other treatments in both cases were similar. The results are given in Tables I and II.

It will be seen from the results given in Tables I and II that sowings done on 10 July or later were practically free from the disease. But late sowings are not recommended as yield is reduced. In a locality where the disease is very serious late sowings would be useful.

(C) Effect of stagnant water

Water is a limiting factor in the success of rice. It is mostly grown in the semi-waterlogged areas. All cultural operations are done

TABLE I

Effect of different dates of sowing

Serial No.	Date of sowing in 1935	Percentage of diseased plants	
		Set A (Plants thinned)	Set B (Plants not thinned)
1	10 May	14·8	15·5
2	25 May	84·1	64·4
3	10 June	42·4	28·0
4	25 June	40·8	18·7
5	10 July	0·0	5·0
6	25 July	0·0	0·0
7	10 August	0·0	0·0
8	25 August	0·0	0·0

TABLE II

Effect of different dates of transplanting

Serial No.	Date of transplanting in 1935	Percentage of diseased plants	
		Set A (Plants thinned)	Set B (Plants not thinned)
1	10 June	43·4	38·4
2	25 June	31·5	33·3
3	10 July	0·0	0·0
4	25 July	0·0	0·0
5	10 August	0·0	0·0
6	25 August	0·0	0·0

in puddled conditions and water is kept stagnant throughout the growing period of the crop.

Ramiah [1937] pointed out that though in India it is considered essential to keep water always in the field throughout the growth of the crop yet in some countries, i.e. Italy, Spain and America, water is drawn off completely from the field now and then. It seems that rice can stand this treatment without any harm.

It was observed that the usual practice of keeping water stagnant in rice fields throughout the growing period, favoured the attack of the stem-rot disease. In order to confirm the observations, field and pot experiments were arranged.

Pots used for this purpose were cemented at the bottom and water was kept standing and maintained by periodical additions. For the study of effect of absence of stagnation in pots, water was applied in small quantities as required to maintain the plants and keep the soil moist. Similarly in the field plots, water was always kept stagnating. On the other hand, from the control plots water was drained off now and then by opening the bunds. For pot experiments No. Jhona 349 was used but in the field 19 varieties of rice were grown. In each pot five seedlings were transplanted. Soil of pots and field was inoculated with the culture of the fungus. Results of pot experiments are given in Table III and the field observations in Table IV.

TABLE III

Effect of stagnant water (pot experiments) in 1935

Pot No.	Percentage of diseased plants	
	Water stagnant	Control (water not stagnant)
I	100·0	0·0
II	100·0	0·0
III	100·0	0·0
IV	33·0	0·0
V	40·0	0·0
VI	25·0	0·0
VII	40·0	0·0
VIII	40·0	0·0
IX	20·0	0·0

TABLE IV

Effect of stagnant water in 1935

Serial No.	Variety	Percentage of diseased plants	
		Stagnant water	Control (water not stagnant)
1	Jhona 349	38·8	0
2	Mushkan 7	0·0	0
3	Sonkesar 225	81·5	4·7
4	Sathra 278	42·3	0
5	Sonpattar 14	50·0	0
6	Mushkan 41	0·0	0
7	38 A	25·0	7·7
8	14 (S)	58·3	0
9	337 (A)	11·1	0
10	Palman 46	23·5	0
11	32	0·0	0
12	K. V. 32	30·0	0
13	Basmati 3	4·2	0
14	128	41·2	25·0
15	Bara 62	13·3	0
16	Basmati 370	0·0	0
17	Dhan 21	57·1	10·0
18	Munji 22	54·7	6·2
19	Ranjha 360	50·0	0

It will be seen from Tables III and IV that the results of both the pot and field experi-

ments establish that stagnant water increases infection to a considerable extent. Periodical drainage of stagnant water results in the total elimination of infection or it appears only in mild form. Reyes [1929] stated that one of the predisposing causes of the disease is the presence of abundance of stagnant water.

Tullis and Cralley [1933] mentioned that of the various control measures the most promising appears to be withholding of stagnant water from the rice fields for some time prior to maturity, though enough should be present to keep the soil muddy throughout the growing season.

(D) Effect of manures

It has been commonly observed that potassic and phosphatic fertilizers tend to reduce the incidence of infection by certain fungi and on the other hand nitrogenous manures have been seen to promote infection. It was, therefore, deemed desirable to study the effect of different manures on the incidence of the stem-rot disease.

Manurial experiments were arranged at the Botanical Farm, Lyallpur in 1935, 1936, 1938 and 1939. For these experiments land was divided into sub-plots each measuring 25 × 6 ft. Between each series of two plots a buffer strip 3 ft. wide unsown was kept. Experimental plots were artificially infected with the culture of the causal fungus.

Six week old seedlings of type Jhona No. 349 were transplanted in 1935 and 1936, while Sonkesar 225 was used in 1938 and 1939.

The following manures were added two weeks after transplanting and control plots were kept.

1. Farmyard manure at the rate of 1000 md. per acre.
2. Sulphate of ammonia at the rate of 5 md. per acre.
3. Superphosphate at the rate of 2½ md. per acre.
4. Potassium chloride at the rate of 2 md. per acre.

The results are given in Table V.

Table V

The Effect of different manures

Serial No.	Treatment	Percentage of diseased plants				Average of all years
		1935	1936	1938	1939	
1	Sulphate of ammonia	13·7	21·9	39·1	36·6	27·8
2	Farmyard manure	4·9	11·4	8·0	18·0	10·5
3	Superphosphate	4·5	8·6	0·0	10·0	5·77
4	Potassium chloride	3·0	7·0	0·7	7·4	4·52
5	No manure (control)	2·9	4·3	1·5	8·3	4·25

From the results given above it will be seen that nitrogenous manures definitely increase infection. In the case of potassic and phosphatic fertilizers the disease was markedly less but it was greater than the control.

Cralley [1939] studied the effect of fertilizers on the stem-rot disease. He stated that nitrogenous and phosphatic fertilizers increased the severity of the disease. He further mentioned that application of potassium on the other hand did not increase the severity of the disease. He recommended the addition of sufficient potassium on the stem-rot infested fields. The authors are of opinion that under the Punjab conditions the addition of potassium will not prove useful The only point of economic importance is to avoid the heavy application of nitrogenous manures in the diseased rice area.

(E) The relative resistance of various varieties of rice

Experiments on the relative resistance of various varieties of Punjab rice to the stem-rot disease were carried out at the Botanical Farm, Lyallpur, and the Government Rice Farm, Kala Shah Kaku. Nineteen varieties of rice were used in the experiment. The experiment was arranged in a naturally infested field at the Rice Farm Kala Shah Kaku, while at Lyallpur it was artificially infected with the culture of the fungus and diseased rice stubble. The results are given in Tables VI and VII.

From the results given in Tables VI and VII. it will be seen that some fine varieties of of Punjab, i.e. Nos. Basmati 370, Bara 62, Mushkan 7, Basmati 3 and Mushkan 41 are highly resistant, while Sathra 278, Sonkesar 225, Sonpattar 14 are most susceptible. The remaining varieties may be called tolerant to the disease.

(F) Control measures

For the direct control of the stem-rot disease of rice some experiments were conducted at the Botanical Farm, Lyallpur, and the Rice Farm, Kala Shah Kaku.

For these experiments a piece of naturally infested land was selected and divided into various sub-plots, each measuring 64 × 10 ft. at the Rice Farm Kala Shah Kaku and 15 × 15 ft. at the Botanical Farm, Lyallpur. Seedlings of variety No. Sonkesar 225 grown in uninfested soil were transplanted in the middle of July every year. The following treatments were carried out and control plots were kept.

1. Burning of rice stubble *in situ*.

TABLE VI

The relative resistance of varieties of rice to the stem-rot disease at Lyalpur

Serial No.	Name of variety	Percentage of diseased plants				Average percentage of diseased plants
		1935	1936	1938	1939	
1	Basmati 370	0	0	0·5	0·0	0·1
2	32	0	0	0	2·5	0·6
3	Mushkan 41	0	0	0·	7·3	1·8
4	Malster 346	..	..	0	3·6	1·8
5	Mushkan 7	0·0	4·5	0	0	1·1
6	Basmati 3	2·1	0	4·6	0·5	1·8
7	Bara 62	6·7	0	0	0	1·7
8	Begmi 337A	5·5	0	0	4·0	2·3
9	Dhan 202	..	..	0	11·3	5·6
10	Dhan K. V. 22	15·0	0	9·5	0	6·1
11	Dhan 21	9·7	0	0·7	2·8	3·3
12	Palman 46	11·7	4·0	4·1	5·3	6·2
13	Ranjha 360	25·0	4·0	0	3·5	8·1
14	Sathra 278	26·1	5·0	0	25·9	14·2
15	Jhona 349	19·4	25·5	0	1·5	19·1
16	128	33·1	28·0	18·9	3·7	20·9
17	38A	16·3	64·0	1·3	3·6	21·3
18	Sonpattar 14	29·2	73·0	22·9	6·7	32·4
19	Sonkesar 225	43·1	42·8	24·8	23·0	33·3

TABLE VII

The relative resistance of varieties of rice to the stem-rot disease of rice at Kala Shah Kaku

Serial No.	Name of variety	Percentage of diseased plants		Average percentage diseased plants
		1935	1936	
1	Bara 62	1·9	0	0·9
2	Mushkan 7	2·3	0	1·1
3	246	0	2·1	1·0
4	Basmati 370	3·3	0	1·6
5	K. V. 6	0	4·2	2·1
6	Jhona 349	3·3	1·4	2·3
7	Mushkan 41	1·0	5·0	3·0
8	Ranjha 360	6·1	0	3·0
9	K. V. 22	8·0	0	4·6
10	Malster 346	..	8·3	8·3
11	257	..	14·2	14·2
12	378	20·2	0	10·0
13	Begmi 337A	29·0	0·5	14·7
14	K. V. 38	28·4	0·9	14·5
15	Sonpattar14	61·8	2·5	32·1
16	Sonkesar 225	..	65·2	65·2
17	Sathra 278	100·0	45·6	72·8

2. Removal of stubble by beans of *Khurpa* (a country made hand tool).

3. Ploughing the rice field, collecting and destroying the stubble thus uprooted.

4. No treatment (control).

The above treatments were carried out after harvesting the crop. The results are given in Table VIII.

TABLE VIII

Results of experiments on the control of the stem-rot disease of rice at Lyallpur and Kala Shah Kaku Farms

Serial No.	Treatment	Percentage of diseased plants at Lyallpur Farm		Percentage of diseased plants at Kalashahkaku Farm		Average percentage of diseased plants
		1935-36	1936	1935	1936	
1	Burning of stubble *in situ*	21·0	14·3	46·8	11·4	23·4
2	Removal of stubble by means of *Khurpa*	3·7	17·7	61·8	17·8	25·25
3	Ploughing and collection of uprooted stubble	12·1	27·1	..	..	19·6
4	No treatment (control)	34·7	30·5	67·2	20·0	38·1

From the results given in Table VIII, it is clear that the burning of stubble *in situ* is fairly effective. This method is cheap and easy to be carried out after harvesting the crop. Hence for simply controlling the disease by the sanitary measures, it is necessary that all the farmers in a locality should work in co-operation and carefully destroy the diseased stubble, which is the main source of carrying infection from crop to crop.

It was observed that the diseased stubble and the sclerotia of the causal fungus after the treatments had been done, were spread by strong winds and rainfall from the untreated to the treated plots. Young [1926] pointed out that infection is spread by soil, stubble and straw. Lester [1928] described that scalerotia are believed to be distributed by the irrigation water.

In order to prevent the importation of infection into fields, on which the effect of burning stubble for control of the disease was studied, the following precautions were adopted. In 1939 a naturally infested plot which had carried 37.8 per cent diseased plants in 1938 was divided into four sub-plots, each measuring 25 × 20 ft. A cross wall three feet high of *kacha* bricks was erected in between the experimental plots. Each plot received irriga-

tion by a separate channel and during irrigation every possible care was exercised not to allow water to pass from one plot to the other.

In two opposite plots burning of stubble *in situ* was done after harvesting the crop in 1938. The other two plots were left untreated. Seedlings of variety No. Sonkesar 225 (which is most susceptible to the disease) were grown in uninfested soil and transplanted on 25 July, 1939. The results are given in Table IX.

TABLE IX

Results of experiment on the control of Sclerotium oryzae *at the Lyallpur Farm in 1939*

Serial No.	Treatment	Total No. of plants	No. of diseased plants	Percentage of diseased plants
1	Burning of stubble *in situ*.	404	0	0
2	Untreated (control) . .	466	87	18·7
3	Burning of stubble *in situ*.	461	0	0
4	Untreated (control) . .	402	27	6·7

From the results given in Table IX, it will be seen that the burning of strubble *in situ* is a very effective operation for controlling the disease. It is suggested, therefore, to isolate the infected area by high and strong bunds, which will serve as effective barriers against the spread of secondary infection by wind and irrigation water.

SUMMARY

1. The importance and distribution of the disease caused by the fungus *Sclerotium oryzae* Catt. has been described. The disease is common in many rice growing districts of the Punjab and causes considerable loss.

2. The effect of certain environmental factors on the incidence of the disease has been studied. The important results are:

(a) Infection is reduced if late sowing and late transplanting are done but these are not recommended.

(b) Keeping water stagnant throughout the growing period of the crop increases the incidence of the disease. If water is drained off now and then the disease is controlled to a great extent.

(c) Application of nitrogenous manures favours the attack of the disease.

3. The relative resistance of 19 varieties of the Punjab rice has been tested. The results show that Basmati and Mushkan groups of rice are most resistant to the disease.

These varieties are:—

Basmati 370,

Basmati 3,

Mushkan 7,

Mushkan 41; and

Bara 62.

On the other hand Sathra and Son groups of rice are most susceptible to the disease and these varieties are:

Sonkesar 225,
Sonpattar 14; and
Sathra 278.

Other varieties tested are intermediate in this respect.

4. Various control measures were tried and the following are recommended.

(a) Diseased rice stubble should be burnt *in situ*.

(b) Strong and high bunds should be made round the infested fields. This will check the spread of the disease by wind and irrigation water.

(c) Water should not be kept stagnant throughout the growing period of the rice crop. Soil should be exposed to open air now and then.

(d) Disease resistant varieties of rice should be grown.

ACKNOWLEDGEMENT

The authors feel grateful to Ch. Sardar Khan, Assistant Cerealist, Kala Shah Kaku, for supplying seed of rice and the facilities provided for the investigation.

REFERENCES

Butler, E. J. (1913). *Agric. Res. Inst. Pusa. Bull.* No. 134

Cattaneo, A. (1879). *Arch. Triene Lab. Critt. Pavia* **2-3**, 75-83

Cralley, E. M. (1939). *Bull. Ark. Agric. Expt. Sta.* 383·17

Lester, W. C. (1928). *Ceylon, Dept. of Agri. Tech. Repts.* 1927, (*i*)-(11), 1928

Luthra, J. C. and Sattar, A. (1936). *Indian J. agric. Sci.* **6**, 973-84

Reyes, G. M. (1929). *Philip. agric. Rev.* **22**, 313-31

Ramiah (1937). *Rice in Madras*—a popular hand book.

Tullis, E. C. and Cralley, E. N. (1933). *Ark. Agric. Expt. Stn. Bull.* **295**

Young, V. H. (1926). *Rice J.* **29** (1), 11-12

SOME RARE AND NEW SMUTS FROM INDIA

By B. B. Mundkur, Imperial Agricultural Research Institute, New Delhi

(Received for publication on 3 March 1943)
(With two text-figures)

MAJORITY of the smuts on which this report based were collected in different parts of India d sent to me for determination. Among those o sent specimens are Dr L. Bor, Mr A. N. idar, Dr P. Maheshwari, Dr B. P. Pal, Dr shkarnath and Mr M. J. Thirumalachar. tions of specimens were also given by Mr K. M. omas from the Coimbatore Herbarium.

I take this opportunity of expressing to all of m my gratitude for the favour they have done donating the specimens. I am also grate- to Rev. Fr H. Santapau, S. J., Professor of tany, St Xavier's College, Bombay, for the n translations of the diagnosis of the new cies. The specimens are deposited in the rb. *Crypt. Ind. Orient.*

USTILAGINACEAE

USTILAGO ANDROPOGONIS-FINITIM Maublanc, Bull. Soc. Mycol. Fr. 22 : 74, 1906

n the ovaries of *Cymbopogon flexuosus* Wats. adi Hill (Mysore), 21 March 1942, leg. M. J. rumalachar. Maublanc was apparently not ain whether his fungus is a *Cerebella* or an *ilago*, for the caption under the figure illustrat- this smut reads " *Cerebella* (*Ustilago*) *Andropo- is-finitimi*". Germination of the spores, which ve observed and which is by means of a septate nycelium and terminal and lateral sporidia, at rest any doubts on this point.

USTILAGO ESCULENTA P. Hennings Hedwigia, 4 : 10, 1895 ; Miyabe, Bot. Mag. Tokyo, 9 : 197, 1895 ; Hori, Ann. mycol. Berl. 5 : 50, 1907 ; Yen, Ann. Cryptog. exot. 7 : 87, 934 (Fig. 1)

the hypertrophied tissues of the culms of *nia latifolia* (Griseb.) Turcz. Imphal (Manipur), . 1940, leg. G. C. Gimson, comm. N. L. Bor 1). Hennings, Miyabe and Zundel state that spores are smooth but according to Hori and , they are echinulate. Hori suggests that the es of his specimen were echinulate because he mined a fresh specimen ; not only are the spores he Imphal specimen echinulate but even those he American specimen (Nov. 11, 1911, leg. ield) show echinulations under the oil immer- objective.

USTILAGO FLAGELLATA Sydow, Ann. mycol erl. 9 : 144, 1911

n. *Sphacelotheca flagellata* Zundel, Bothalia- 10, 1938.

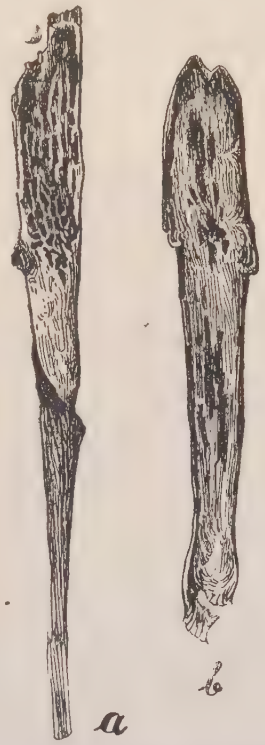

FIG. 1. Culms of *Zizania latifolia* affected by smut
a. Advanced case of attack
b. A culm recently attacked

In the ovaries of *Rottboellia exaltata* L.f. Anamalai (Madras), 18 January 1923, ex Herb. Coimbatore, No. 1321A. A columella is present but there is no true peridium ; the membrane covering the spores is made of host tissue.

4. USTILAGO IMPERATAE Mundkur sp. nov.

Sori penitus destruentes inflorescentiam, inclusi vagina atque cooperti membrana pallida nigra ; membrana postea flocculat, nigris pulverulentisque sporis expositis ; columella longorum frustulorum instar ; cellulae steriles nullae. Sporae ex sphaericis ad ovatas, nonnullae tenuiter angulares et ideo, ut videtur, triangulares ; quae in cellula continentur granulata ; colore " natal brown " (Ridgway), diam. 13·0-18·7μ (med. 16·0μ) ; episporium crassum laeve ; germinatio per septatum promycelium lateralibus atque terminalibus sporidiis ornatum.

Typus legit N. L. Bor die 20 junii 1942 in inflorescentia Imperatae cylindricae Beauv. in loco Kohima, in montibus Naga, Assam.

Sori entirely destroying the inflorescence, enclosed by the sheath and covered by a greyish-black membrane made of host tissue ; membrane later flaking away revealing black, pulverulent spores ; columella in the form of long shreds ; no sterile cells. Spores spherical to oval, some slightly angular therefore appearing triangular, with granular contents, " natal brown " (Ridgway), 13·0—18·7μ in diameter with a mean of 16·0μ ; epispore 1μ thick, smooth ; germination by means of a septate promycelium with lateral and terminal sporidia.

In the inflorescence of *Imperata cylindrica* Beauv. Kohima, Naga Hills (Assam), 20 June 1942, leg. N. L. Bor (Type). *Sphacelotheca Schweinfurthiana* (Thuem.) Sacc. which is also on this host, is ovaricolous, its spores being minutely warty and 9·3 to 14·5μ in diameter. *Sphacelotheca nankinensis* Zundel also on this host has light reddish-brown, smooth spores with a diameter of 4-6μ.

5. USTILAGO TRAGI Mundkur sp. nov.

Sori destruentes ovaria, turgidi, 5-8 mm. longi, 4-5 mm. lati, colore rubro-brunneo (mahogany), prominentes ex superioribus glumis involucralibus, atque cooperti densa membrana ; columella sterilesve cellulae nullae. Sporae globosae, subglobosae, vel elongatae ovatae, colore " cinnamon buff " (Ridgway), diam. 7·2—13·0μ (med. 10·4μ) ; episporium tenue, graciliter atque breviter echinulatum.

Typum legit P. V. Somayajulu die 24 novembris 1917 (ex herb. Coimbatorensi No. 969) in ovariis Tragi biflori Schult. (=Tragi racemosi Scop.), in loco Coimbatore (Madras).

Sori destroying the ovaries, swollen, 5 to 8 mm. long, 3 to 4 mm. broad, mahogany coloured, protruding out of the upper involucral glumes and covered by a thick membrane made of host tissue ; without columella or sterile cells. Spores globose, subglobose to elongate oval, " cinnamon buff " (Ridgway), 7·2 to 13·0μ in diameter (mean= 10·4μ) ; epispore thin with delicate and short echinulations.

In the ovaries of *Tragus biflorus* Schult. Coimbatore (Madras), 24 November 1917, leg. P. V. Somayajulu, ex Herb. Coimbatore, No. 969, (type).

6. CINTRACTIA DISVANS Mundkur sp. nov. (Fig. 2)

Sori in basi rhachidis floralis, turgidi, circa 10-15 mm. longi, cooperti membrana brunnea ; membrana postea dehiscens, sporarum exposita nigra massa agglutinata et haud facile separabili. Sporae sphaericae ad ovatas, nonnullae tenuiter elongate ellipsoidaeae, colore " snuff brown " (Ridgway), diam. 8·9—13·2μ (med. 11·2μ) ; episporium ca. 1μ crassum, prorsus laeve.

Typum legit P. Maheshwari mense augusto 1940 in basi rhachidis inflores-centiae Caricis distantis Willd. (ex Kunth), in loco Dac (Bengal).

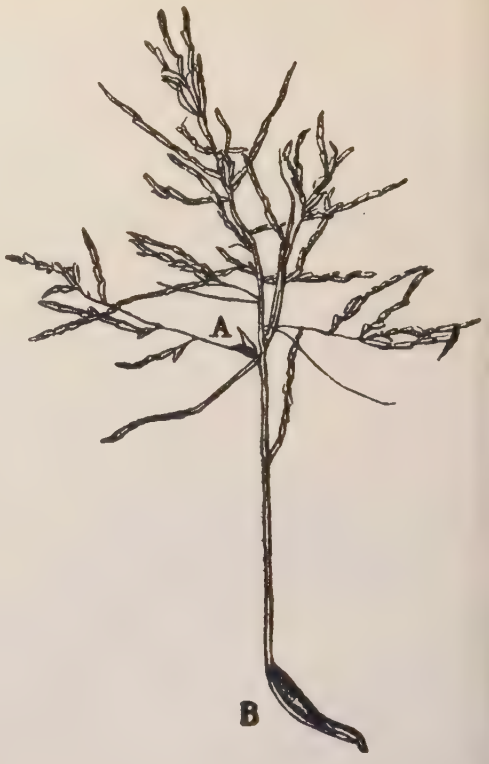

FIG. 2. Inflorescence of *Carex distans* attacked by sm A and B, sori formed at the base of the rhachis

Sori at the base of the floral rhachis, swoll about 10 to 15 mm. long, covered by a brown membrane of host tissue ; membrane later def cing, revealing a black, agglutinated spore-m difficult to separate. Spores spherical to o some slightly elongate-ellipsoidal, " snuff brow (Ridgway), 8·9μ to 13·2μ in diameter (mea 11·2μ) ; epispore about 1μ thick, entirely smoo

At the base of the rhachis of the inflorescence *Carex distans* Willd. ex Kunth, Dacca (Beng August 1940, leg. P. Maheshwari (Type).

7. SPHACELOTHECA CHLORIDIS Mundkur sp. no

Sori destruentes omnia ovaria in inflorescent racemo, cooperti falsa membrana quae tanc flocculat, revelata sporarum massa brunneo-ni fere pulverulenta. Columella prominens, si lex ; cellulae steriles catervatim quinae ad de coactae. Sporae sphaericae ad ellipsoida brunneae " Kaiser brown " (Ridgway), di 6·0—9·3μ, med. 7·2μ ; episporium minute e nulatum, tenue ; germinatio per septatum mycelium terminalibus atque lateralibus spori ornatum.

Typum legit M. J. Thirumalachar in ova Chloridis barbatae Sw. in loco Bangalore (Mys die 20 augusti 1942.

Sori destroying all the ovaries in a raceme, covered by a false membrane which utlimately flakes away revealing brownish-black, almost pulverulent spore mass ; columella prominent, simple ; sterile cells in groups of five to ten. Spores spherical to ellipsoidal, " Kaiser brown " (Ridgway), 6·0 to 9·3μ in diameter (mean=7·2μ) ; epispore minutely echinulate, thin ; germination by formation of septate promycelium with terminal and lateral sporidia.

In the ovaries of *Chloris barbata* Sw. Bangalore (Mysore), 20 August 1942, leg. M. J. Thirumalachar (Type).

8. Sphacelotheca tricholaenae (P. Henn.) Mundkur comb. nov.

Syn. *Ustilago Tricholaenae* P. Hennings, Engler' bot. Jb. 17 : 3, 1893 ; Sydow, Svensk bot Tidskr. 29 : 67, 1935.

Sori entirely destroying the ovaries, all of which in a panicle attacked ; enclosed by a leathery, persistent, brownish-black, false membrane, dehiscing at the side, revealing dark brown, slightly pulverulent spore-mass ; columella prominent, simple ; sterile cells smooth, 12μ in diameter, in groups. Spores spherical, subspherical to ellipsoidal, " russet " (Ridgway), 7·1 to 10·8μ in diameter (mean = 8μ) ; epispore rather thick, minutely punctate.

In the ovaries of *Tricholaena teneriffae* Parlat, Sind, Comm. N. L. Bor (material is undated and exact locality in Sind is not stated). Hennings studied two specimens, the type collected in Arabia and another collected in Egypt ; the only other collection appears to be the one made in 1933 by G. Samuelsson in Palestine and identified by Sydow. Hennings states that the sori are 2-4 cm. long and 1 cm. broad but those of the Sind specimen are much smaller. In all other respects, it agrees with Hennings's description.

9. Tolyposporium cymbopogonis Mundkur sp. nov.

Sori destruentes inflorescentiam, 2-4 cm. longi, 5·8 mm. lati, inclusi falsa membrana colore flavo-albida, persistente ; membrana dehiscens irregulariter, revelatis sporarum sphaericis massis nigris ; columella prominens, tenuis, simplex, aeque longa ac sorus vel paulisper longior ; sporarum massae subglobosae ellipsoidales vel irregulares, persistentes, haud facile resolutae in sporas, magnitudinis 29-83×25-62μ. Sporae peripherales sphaericae vel subsphaericae, tenuiter polygonales, minute echinulatae atque excavatae, brunneae " Kaiser brown " (Ridgway), diam. 6·5-11·2μ (med. = 8·6μ) ; interiores sporae polygonales laeve episporio coopertae, colorae clariori ; germinatio per septatum promycelium lateralibus atque terminalibus sporidiis ornatum.

Hab. in inflorescentia Cymbopogonis citrati Stapf, leg. M. J. Thirumalachar in loco Bangalore (Mysore), die decembris 1941.

Sori destroying the inflorescence, 2 to 4 cm. long and 5 to 8 mm. broad enclosed by cream coloured, persistent, false membrane, dehiscing irregularly revealing masses of black spore balls ; columella prominent, slender, simple, as long or slightly longer than the sorus ; spore balls subglobose, ellipsoidal or irregular, permanent, disintegrating into spores only with difficulty, 29-83×25-62μ. Spores at periphery spherical to subspherical, slightly polygonal, minutely echinulate and pitted, " Kaiser brown " (Ridgway), 6·5 to 11·2μ in diameter (mean=8·6μ) ; inner spores polygonal with smooth epispore and lighter colour ; germination by means of septate promycelium forming lateral and terminal sporidia.

In the inflorescence of *Cymbopogon citratus* Stapf, Bangalore (Mysore), 20 December 1941 leg. M. J. Thirumalachar (Type).

TILLETIACEAE

10. Tilletia brachypodii Mundkur sp. nov.

Ovaricola ; ovaria affecta haud leviter turgida, 10-25 mm. longa, 5-6 mm. lata, cooperta membrana plumbei coloris quae flocculat revelatis intus sporarum massis intense nigris atque tenuiter agglutinatis ; cellulae steriles magnitudine minores quam sporae, sphaericae, relative tenui pariete instructae. Sporae globosae vel subglobosae, brunneae 'hessian brown' (Ridgway), diam. 13·0-22·3μ (med.=16·9μ) ; episporium crassum, irregulariter verrucosum ; singulae sporae membrana evidenti atque hyalina obtectae. Germinatio post longum quietis periodum, formatis non-septato promycelio atque terminalibus sporidiis.

Typum legit K. M. Dutt in ovariis Brachypodii sylvatici Beauv. in loco Simla (Punjab), die 20 octobris 1942 ; idem, die 17 novembris 1941 ; Pushkarnath legit mense novembri 1942.

Ovaricolous ; attacked ovaries considerably swollen, 10-25 mm. long and 5-8 mm. broad, covered by an evanascent greyish-membrane which flakes away revealing deep-black, slightly agglutinated spore-masses within ; sterile cells smaller in size than spores, spherical, comparatively thin-walled. Spores globose to subglobose, " hessian brown " (Ridgway), 13·0 to 22·3μ diameter (mean=16·9μ) ; epispore thick with irregular verruculations ; each spore enveloped in an evident, hyaline membrane ; germination after a prolonged rest period by the formation of a non-septate promycelium and terminal sporidia.

In the ovaries of *Brachypodium sylvaticum* Beauv. Simla (Punjab), 28 October 1942, leg. K. M. Dutt (Type) ; also on 17 November 1941 ; November 1942, Pushkarnath. *Tilletia olida* (Reiss) Winter on *Brachypodium pinnatum* PB.

and *Brachypodium sylvaticum* is a leaf smut whose spores are 16 to 26μ in diameter. Comparison (Sydow *Ust.* No. 319) indicates that the two are different.

11. TILLETIA CARIES (DC.) Tulasne, Ann. Sci. nat. Bot. III, 7 : 113, 1847 ; Butler and Bisby, Sci. Monogr. Coun. agric. Res. India, 1 : 46, 1931
Syn. *Uredo caries* DC. Flore Fr. 6 : 78, 1815
Tilletia Tritici Winter, in Rabenhorst Kryptogamenfl. 1 : 110, 1881

In the ovaries of *Triticum vulgare* Host, New Delhi, April 1941, leg. B. P. Pal. This is the first authentic record of this bunt for the Indian plains. Seed, from which the crop at New Delhi was raised, appears to have come from Baluchistan. Apparently it was infected and conditions in Delhi may have been conducive for the crop to become slightly affected. This bunt is recorded for Sind by Uppal, Patel and Kamat but specimens are not available and its occurrence is doubtful.

12. TILLETIA FOETIDA (Wallr.) Liro, Die Ustilagineen Finnlands, 2 : 87, 1930
Syn. *Erysibe foetida* Wallroth, Fl. Cryptog. Germanie, 2 : 213, 1833. *Tilletia laevis* Kühn, in Rabenhorst Fungi europ. No. 1697, 1873. *Tilletia foetans* Trelease, Trans. Wis. Acad. Sci. Art. Lett. 6 : 139, 1886 ; Butler and Bisby, Sci. Monogr. Coun. agric. Res. India, 1 : 46, 1931

In the ovaries of *Triticum vulgare* Host, New Delhi, April 1941, leg. B. P. Pal. This appears to be the first authentic record of this fungus for the Indian plains. Seed came from Baluchistan and may have brought the infection. Specimens of this bunt recorded by Uppal, Patel and Kamat for Sind are not available and its occurrence there is doubtful.

13. TILLETIA KOELERIAE Mundkur sp. nov.

Sori destruentes ovaria, inclusi membrana plumbei coloris quae postea flocculat, revelata sporarum massa nigra ; ovaria affecta globosa vel ovata, tenuiter turgida, 4-8 mm. diam. Sporae pulverulentae, ovatae vel elongatae ellipsoidales, saepe irregulariter polygonales, brunneae " Brussel's brown " (Ridgway), diam. 16·7-26·0×9·3×5μ, (med.=20·9×18·3μ) ; episporium crassum 1·5-2·5μ, dense minutissimis verrucis distinctum ; germinatio formato non-septato promycelio terminalibus sporidiis ornato.

Typum legit B. P. Pal in ovariis Koelariae cristatae Pers. in loco Simla (Punjab) die 21 maji 1942 ; materia collecta exigua.

Sori destroying the ovaries, enclosed by a greyish membrane which later flakes away revealing a black spore-mass ; attacked ovaries globose to oval, slightly swollen, 4 to 8 mm. in diameter. Spores almost pulverulent, oval to elongately ellipsoidal, often irregularly polygonal, " Brussel's brown " (Ridgway), 16·7-26·0×9·3-20.5μ in diameter with a mean of 20·9×18·3μ, epispore 1·5 to 2·5μ thick, densely covered with very minute warts ; germination by formation of an unseptate promycellium forming terminal sporidia.

In the ovaries of *Koeleria cristata* Pers. Simla (Punjab), 21 May 1942, leg. B. P. Pal (Type material scanty). Another species of *Tilletia* on this host is *Tilletia sterilis* Ule, whose sori occur in the form of long yellowish-grey stripes in the leaves. Its spores are reported to be smooth, and 20-30×18-24μ in diameter. Systematic position of *Tilletia sterilis* is in doubt for Massee (Kew Bulletin, 1899, p. 157) did not consider it to be as mut

14. TILLETIA PENNISETINA Sydow, Ann. mycol. Berl. 27 : 421, 1929 ; Mundkur, Trans. Brit. mycol. Soc. 23 : 104, 1939

In the ovaries of *Pennisetum orientale* Rich. Simla Oct. 1942, leg. Pushkarnath

15. NEOVOSSIA INDICA (Mitra) Mundkur, Trans. Brit. mycol. Soc. 24 : 313, 1940

In the seeds of *Triticum vulgare* Host, New Delhi 1942 ; Islamnagar (United Provinces) 1942 Mirpurkhas (Sind) 1941, leg. N. Prasad

16. ENTYLOMA BIDENTIS P. Hennings, in Engler Pflanzenwelt Ostafrikas, etc. C. 5 : 49 1895

In the leaves of *Bidens pilosa* L. Bangalore (Mysore), 1 January 1942, leg. M. J. Thirumalachar

17. UROCYSTIS CARICINODES (Berk. and Curt.) Fischer de Waldh. Apercu Syst. Ustilagineen p. 38, 1877

On stems and petioles of *Cimcifuga foetida* L. Gujmarg (Kashmir), June 1940, leg. A.N. Fotidar

18. UROCYSTIS STIPAE McAlpine, Smuts of Australia, p. 198, 1910 ; Clinton and Zundel, Mycologia, 30 : 281, 1938

In the leaves of *Stipa tortilis* Desf. Kohat (N.-W. F.P.) 1942

19. UROCYSTIS TRITICI Koernicke, Hedwigia 16 33, 1877 ; Butler and Bisby, Sci. Monogr. Coun. agric. Res. India, 1 : 42, 1931

On leaves of *Triticum vulgare* Host, Dindori Mandla Dt. (Central Prov.), 1 January 1943 Deshpande. This is the first record of this smut for Central India.

SUMMARY

This paper reports the occurrence of 19 species of smuts hitherto unrecorded for India, of which seven are proposed as new species and one as new combination. *Tilletia caries* and *Teilletia foetida* are reported from the Indian plains apparently for the first time. The range of occurrence of *Neovossia indica* and *Urocystis Tritici* has been widened, as the former is now reported to occur in the United Provinces and Sind, and the latter in Central India, in addition to the Punjab and the N.-W. Frontier Province.

FURTHER NOTES ON THE BIONOMICS OF *BEMISIA GOSSYPIPERDA* M. & L., THE WHITE-FLY OF COTTON IN THE PUNJAB

By K. N. Trehan, M.Sc. (Pb.), Ph.D.(London), Agricultural Entomologist to Government, Bombay, Poona

(Received for publication on 15 May 1943)

(With four text-figures)

The white-fly of cotton has been recognized as a major pest in the Punjab and damages the cotton crop very seriously. Although it is not solely responsible for bringing about periodic failures of this crop in the Province, yet it plays a very important role as a contributive factor.

The life-history, bionomics, nature of damage and the control have been thoroughly studied and the results published separately. The present contribution, however, includes some additional data with respect to the items of bionomical interest studied during the course of these investigations.

The entire work was carried out at Lyallpur under the scheme financed by the Indian Central Cotton Committee. The scheme was originally sanctioned in 1931 for three years, but it was subsequently extended for a further period of two and a half years up to 30 September, 1936. The encouragement and generosity of the Committee is gratefully acknowledged.

The author is very much indebted to Khan Bahadur M. Afzal Husain for his guidance and valuable suggestions during the course of these investigations at Lyallpur, and for his criticisms while going through the manuscript.

The statistical analysis of the data was taken up by Mr Dwarka Nath Nanda, Assistant to the Cotton Research Botanist, Lyallpur. His help is highly appreciated.

Behaviour of the adults

The life-history of *B. gossypiperda* has been fully dealt with in a previous contribution [Husain and Trehan, 1933]. Further observations on this aspect of the problem, however, are discussed below :

i. Sex proportion in nature

Counts of about 8,000 adult white-flies from March to May yielded 22 per cent males. It may, therefore, be presumed that the overwhelming majority of females may be responsible to a great extent for excessive Parthenogenesis during that period.

ii. Attraction to different colours

Lloyd [1922] contributed on the colour tropism of *Avaporariorum*, and stated that both sexes were attracted to yellow traps. He further suggested that partial check might be devised by coloured traps. Observations, therefore, were made to study the relative attraction of *B. gossypiperda* adults, to various colours, and aqueous solutions of the following stains were tried : fuchsin (bright red), Cango red (blood red), eosin (orange red), picric acid (yellow), mythyl green (dark green), mythyl blue (blue), gentian violet (violet), pot. permanganate (purple), Orange G. (orange), pot. bichromate-light (light orange), yellow green (from the bazar) and water (colourless). Experiments were performed in a cage measuring $2 \times 2 \times 1 \cdot 5$ ft. and lined with muslin at the sides as well as at the top. Lower 9 in. of the cage was covered with black-oil cloth to cut off the light in that region. Glass tubes of uniform size were filled with the coloured solutions and were hung against the inner walls of the cage at uniform distances from each other. Three such tubes were hung against each wall. Outer side of each tube was smeared with a transparent mixture of gloy and glycerine. Adults of cotton white-fly were collected in a glass chimney and were allowed to escape within the cage, one by one, through a small hole in the card board which was placed on the mouth of the chimney.

Observations were made from 11 A.M. to 4.0 P.M. daily and the captures recorded are shown in Table I.

The above data are further represented in Table II in the light of the percentage of attraction to various colours. It is obvious from these figures that the maximum attraction, on the whole, was noticed for yellow-green and yellow. Orange, blood red, blue and light orange were intermediate in this respect, whereas the colourless, bright red, orange red and purple attracted least. The position of the violet and dark green, however, was doubtful.

iii. Range of flight

Since *B. gossypiperda* continues to breed on a very large number of alternative hosts, both cultivated and wild, and practically throughout the year as shown by Husain, Trehan and Verma [1936] it is not possible to investigate the problem of the range of its flight unless a given locality is made absolutely free from this pest. In the circumstances, the best that could be done was to estimate the height to which these insects are

TABLE I

Relative attraction of B. gossypiperda *to various colours*

Colours	Captures under different observations						Remarks
	I	II	III	IV	Total	Average	
Yellow-green	227	112	29	31	399	99·8	Each colour was tried in N., S., E.,or West direction under different observations.
Yellow	120	34	144	30	328	82·0	
Orange	182	6	22	2	212	52·5	
Blood red	155	5	30	..	190	47·5	
Violet	177	1	11	..	189	47·3	
Blue	32	1	81	1	115	28·8	
Light orange	35	37	2	14	88	22·0	
Dark green	..	46	2	20	68	17·0	
Purple	..	58	3	5	66	16·5	
Orange red	4	7	18	..	29	7·3	
Colourless	10	11	..	..	21	5·3	
Bright red	9	10	..	1	20	5·0	
Total	951	328	342	104	1725		

TABLE II

Percentage of attraction to various colours

Colours	No. of observations				Average percentage of attraction
	I	II	III	IV	
Yellow-green	23·87	34·15	8·48	29·81	24·08
Yellow	12·61	10·37	42·10	28·84	23·48
Orange	19·13	1·83	6·42	1·92	7·33
Blood red	16·30	1·52	8·77	..	6·65
Violet	18·61	0·30	3·21	..	5·53
Blue	3·36	0·30	23·69	0·96	7·08
Light orange	3·68	11·28	0·59	13·46	7·25
Dark green	..	14·02	0·59	19·23	8·46
Purple	..	17·68	0·88	4·81	5·84
Orange red	0·42	2·13	5·26	..	1·95
Colourless	1·05	3·35	..	..	1·10
Bright red	0·94	3·05	..	0·96	1·24

capable of reaching. Therefore, some cotton seedlings which were grown in pots and kept free from the white-fly attack, were placed on the roof of the Agricultural College, and that of the College Hostel. The height of the roofs was approximately 40 ft. and the distance from the nearest cotton field was about 150 yd.

After a short exposure of a few days, adults and eggs of *B. gossypiperda* were recorded on these seedlings. It is, therefore, obvious that this insect is capable of reaching up to 40 ft. above the ground level and as the insect is very minute it is also expected that it may get carried long distances by wind. Presumably its distribution in localities where wind storms occur, may be very wide.

iv. Oviposition

(*a*) *Comparative oviposition on different regions of a plant.* Three plants each with three top, middle or bottom leaves were enclosed under a cage. For each observation 150 newly emerged adults of white-flies were introduced in the ca and the eggs laid on different leaves were count after 24 hours. On an average, 51·5 per ce of the total eggs were laid on the top leav 46·7 per cent on the middle leaves and only 1 per cent on the bottom leaves. Field observ tions also confirmed these results as the high number of eggs were found on the top leaves, a the number of eggs decreased as we proceed wards the base of the plant. In captivity, ho ever, the eggs may be laid even on the stumps defoliated seedlings, and may hatch, but nymphs do not develop under these conditio

(*b*) *Selection of leaf surface for oviposition.* nature the eggs are invariably deposited on t lower surface of leaves. In captivity, howev a few eggs may also be laid on their upper surfa To ascertain whether this was the result of to graphical position or the peculiar structure of two surfaces or due to certain deeply pla behaviour of the pest, the following observati

vere made : the leaf petiole was twisted in such a manner that the normal dorsal surface of the leaf became ventral and the leaf was held in this position. A known number of the adult white-flies was liberated on the leaf under muslin sleeves and number of such experiments were performed. On an average, approximately 80 per cent of the eggs under observation, were laid on the natural lower surface even when it was turned upwards. It may be presumed that some structural peculiarities confined to the lower surface to which the adults are very sensitive, might be responsible for this behaviour.

(c) *Oviposition in relation to constant temperature.* The effect of some constant temperatures on oviposition was studied in incubators. No eggs were laid when the insects were kept at 19°C. Of the total number of eggs laid 0·2 per cent were laid at 21°C., 3·8 per cent at 24°C., 9.6 per cent at 27°C., 14.3 per cent at 30°C., 24·3 per cent at 33°C., 24·1 per cent at 35°C. and 23·6 per cent at 37°C., as shown in Table III. The temperatures

TABLE III

Oviposition under constant temperatures—May-June 1933

No of females liberated	Total number of eggs laid at—								Remarks
	19°C.	21°C.	24°C.	27°C.	30°C.	33°C.	35°C.	37°C.	
25	0	..	..	..	..	..	..	..	Observations at
,,	0	..	..	..	..	..	..	..	19°C. taken
,,	0	..	..	..	..	..	..	..	only for 4 days
,,	0	..	1	..	..	..	..	..	and on 37°C.
,,	..	..	3	..	..	..	..	..	only for 5 days.
,,	..	..	7	..	..	..	..	..	Maximum egg
,,	..	..	..	..	..	..	65	19	laying was
,,	..	..	..	..	..	..	..	14	noticed between
,,	..	..	..	..	..	..	51	24	33° & 37°C. and
,,	..	..	..	..	..	..	..	42	lowest at 21°C.
,,	..	..	..	..	..	144	..	27	
15	..	0	4	8	17	47	..	..	
,,	..	1	6	9	13	22	19	..	
,,	..	0	4	12	12	29	23		
,,	..	0	3	14	16	23	21		
,,	..	0	4	7	17	18	25		
10	..	1	..	..	14	17	20		
,,	..	4	..	..	42	18	7		
12	..	..	..	..	8	39	30		
,,	..	0	..	..	24	..	15		
10	0	0	..	..	19	30	18		
,,	..	0	..	..	6	19	..		
,,	..	0	2	..	5	6	5		
,,	..	0	..	..	14	..	..		
,,	..	0	5	..	..	..	..		
,,	..	1	2	6	11	25	..		
,,	..	0	1	10	12	..	..		
,,	..	0	2	4	7	..	..		
,,	..	0	4	10	14	8	..		
,,	..	0	2	3	7	20	..		
,,	..	0	8	17	22	10	..		
,,	..	0	4	8	10	31	..		
,,	..	0	4	9	8	13	..		
15	..	0	3	7	13	11	..		
10	..	0	7	11	17	17	..		
15	..	0	9	13	18	20	..		
,,	..	0	5	7	14	25	..		
,,	..	0	11	16	25	20	..		
,,	..	0	6	15	25	31	..		
,,	..	0	4	11	15	17	..		
,,	..	0	5	11	20	15	..		
,,	..	0	12	17	7	24	..		
15	..	0	2	5	15	35	..		
,,	..	0	5	18	23	21	..		
,,	..	0	..	..	..	32	..		
Totals .		7	135	248	489	777	309	126	
verage No. of eggs per observation	0	0·2	4·1	10·3	15·3	25·9	25·9	25·2	
ercentage of egg laying different temperatures	0	0·2	3·8	9·6	14·3	24·3	24·1	23·6	

ranging from 33°C. to 37°C., therefore, were most suitable. This fact provides explanation for the phenomenon that the most active period for multiplication of the pest is during May to September, when the average maximum temperature ranges from 33°C. to 41°C.

Relative incidence on different varieties of cotton

Since various varieties of cotton are under cultivation in the Punjab the varietal susceptibility and relative preference by the pest, was considered to be a valuable problem. It is presumed that our knowledge about the varietal susceptibility or resistance, may ultimately help in determining the control of the pest, firstly by encouraging the resistant varieties and secondly by combating the pest at the right time when its activity is well pronounced on a particular crop.

It has already been pointed out by Husain and Trehan [1933] that the white-flies are no respectors of varieties and that both *desi* and American varieties are attacked although the incidence of attack differs according to the season. This view is further supported by the observations made during the five years when these investigations were in progress.

During 1931-33, *mollisoni* and 4F. as represen tives of *desi* and American cottons respectiv were compared. *Desi* varieties on the whole, comparatively more infested during the grow period, till about the end of August. After th the infestation, as a rule, declines considerably all the varieties but the attack is relatively hig on the American types (Fig. 1). Towards the of the season, however, the attack increases o again, on the *desi* varieties, as new leaves spr and the pest is attracted to them.

During 1934 and 1935, some of the new selecti of American cottons were compared with the type *mollisoni* and the American types 4F 289F (Table IV). The incidence of white attack was extremely low during both the ye but the relative attack on different varieties foll ed almost the same cycle as previously observe at first *mollisoni* showed a relatively higher att than any of the American types in both the ye but during September and October in 1934 later half of August and early September in 1 the infestation increased relatively on some of American strains namely 4F and L.S.S. wards the end of the season, however, the att again increased on *mollisoni* (Fig. 2).

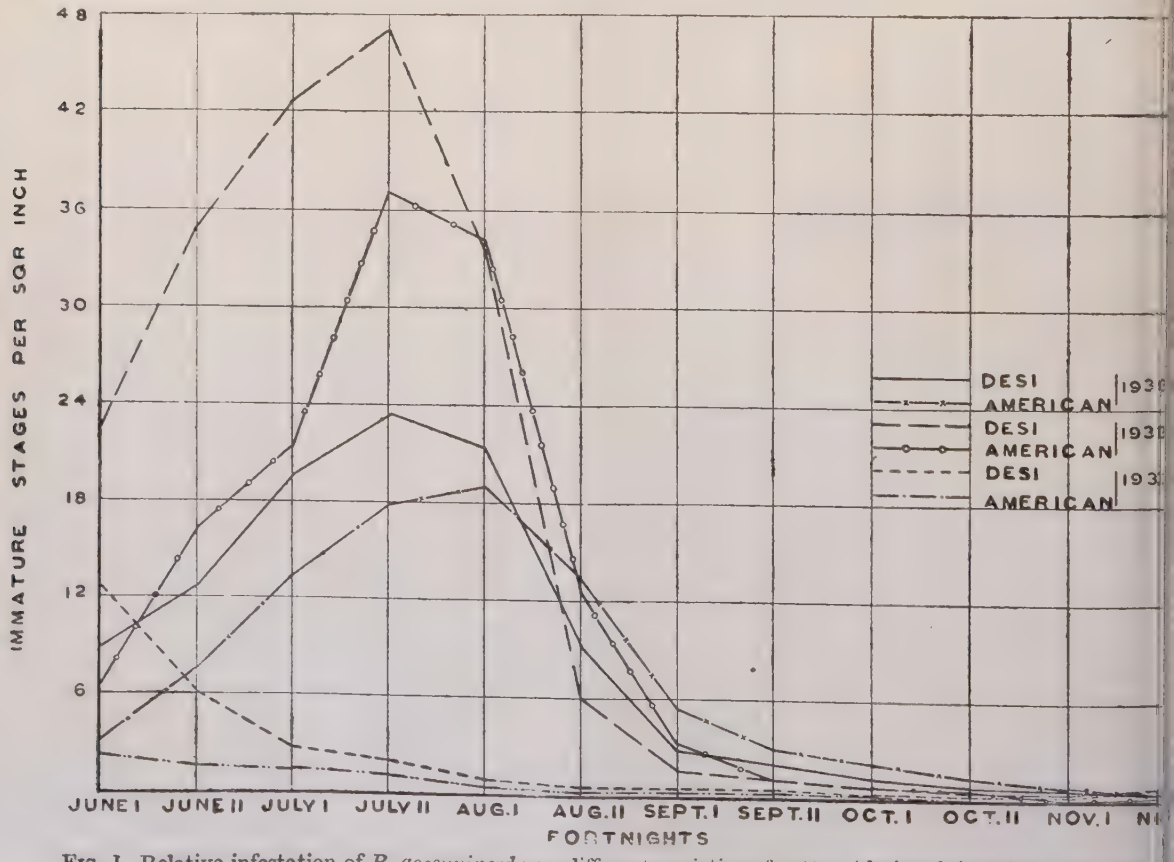

Fig. I. Relative infestation of *B. gossypiperda* on different varieties of cotton (*desi* and American) 1931-33

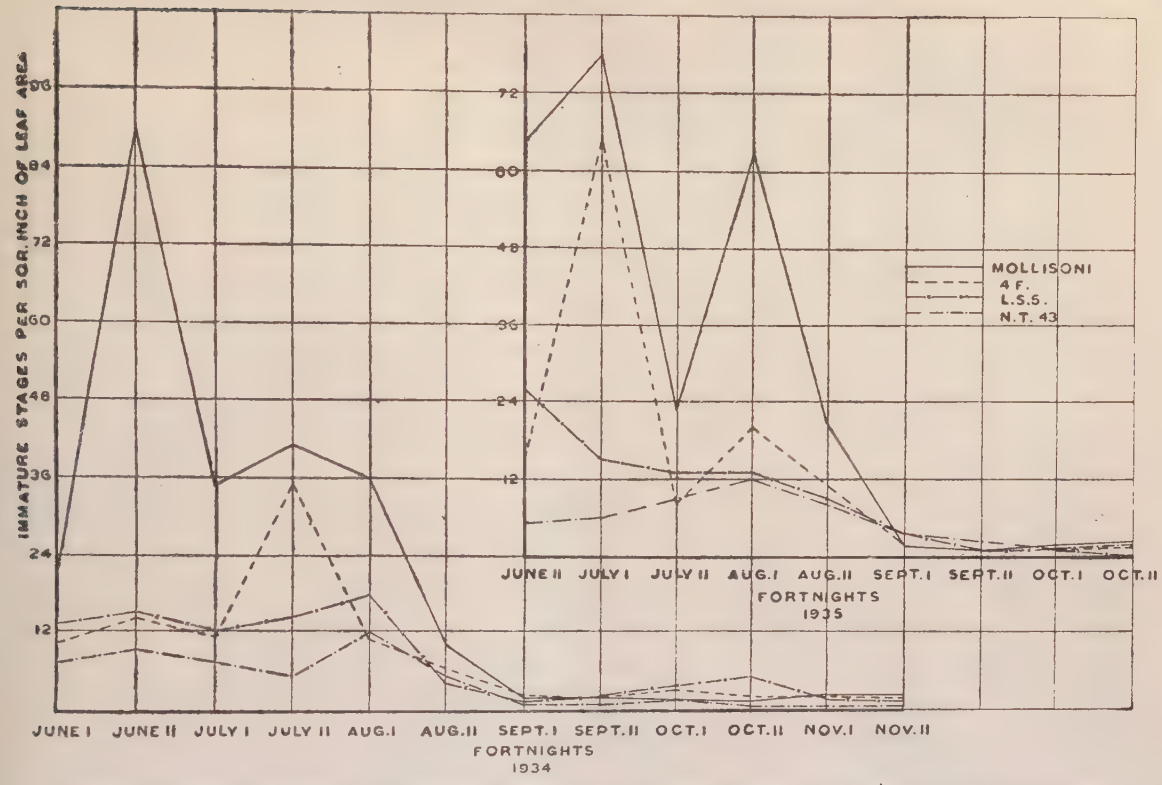

Fig. 2. Relative incidence of *B. gossypiperda* attack on different varieties of cotton in 1934 and 1935

Taking the entire season the white-fly attack on *desi* cotton was significantly higher than on the American cottons during both the years. The attack on American cottons, however, did not differ significantly as well as in the order of significance as shown in Table V. As is obvious from the data given above, of the relative attack on American varieties the severest infestation was noticed on 4 F against the least attack on N. T. 43 (Fig. 2), since the figures for N. T. 38 have not been considered due to irregular observation during 1935.

To determine the causes for the change-over of the relative infestation from *desi* to American varieties and *vice versa*, observations were made on (1) variations in the *p*H values of cell sap in *desi* and American varieties and (2) their moisture contents.

(1) Some insects show a degree of preference for certain hosts during different seasons. According to Jackson [1934] this phenomenon is probably brought about by the condition of the sap, which represents the physiological state of the plant. Acidity being an index of this change *p*H, reactions of the two common varieties namely, *mollisoni* and 289F. representing the *desi* and American types respectively were studied when grown under identical conditions.

The investigations carried out in this connection have shown that the *p*H gradients from top to bottom leaves of a plant varied with its age. The differences were not so marked in the very early stage of growth, but later on the *p*H increased from top to bottom. Towards maturity, however, these variations became erratic and the top leaves in *desi* and the middle ones in general showed the highest *p*H. Similar gradients in *p*H have also been observed by Hass [1920], Gustafson [1924] and Mukerji [1928].

The range of variations in the *p*H value of leaves from the different regions of a plant under observation, is shown in Tables VI and VII.

During 1932, when white-fly infestation was high on both the varieties, the *p*H values for 289F, were on an average, slightly lower than those of *mollisoni* till the end of June. After this they equalized or those of 289F increased slightly. During August the values again increased in the *desi* variety and the differences widened as the plants reached maturity. The incidence of white-fly attack corresponded with the trend of the *p*H curve indicating partiality towards higher values, and therefore, was suggestive of some correlation with the reaction in the plant juice. The infestation, however, was not affected immediately

TABLE IV

Relative incidence of B. gossypiperda *attack on different varieties of cotton in 1934 and 1935*

Year and month	Fortnight	*Mollisoni*			4F			289F			L. S. S.			N. T. 38					
		Leaf area examined	Immature stages	Infestation per sq. in.	Leaf area examined	Immature stages	Infestation per sq. in.	Leaf area examined	Immature stages	Infestation per sq. in.	Leaf area examined	Immature stages	Infestation per sq. in.	Leaf area examined	Immature stages	Infestation per sq. in.	Leaf area examined	Immature stages	Infestation per sq. in.
1934																			
June	I	38·09	87	2·28	28·27	28	0·99	28·86	22	0·76	36·83	48	1·30	24·03	30	1·24	32·34	24	0·74
	II	100·64	901	8·97	97·31	135	1·38	92·38	73	0·79	91·01	133	1·46	86·40	30	0·34	76·67	66	0·86
July	I	75·19	261	3·47	199·58	229	1·14	146·67	61	0·41	151·50	186	1·23	245·52	83	0·33	232·23	151	0·65
	II	327·92	1339	4·08	270·98	958	3·53	391·74	558	1·42	457·85	634	1·38	278·99	143	0·51	463·75	243	0·52
August	I	492·75	1753	3·55	1313·57	1398	1·06	936·96	1110	1·18	746·08	1359	1·82	1008·28	503	0·49	886·76	1079	1·21
	II	536·19	512	0·95	1736·12	795	0·62	924·63	189	0·20	969·39	400	0·41	901·99	266	0·29	971·39	486	0·50
September	I	573·32	82	0·14	1808·92	295	0·16	1580·84	113	0·07	1192·62	94	0·07	897·47	71	0·07	1284·50	63	0·05
	II	727·69	95	0·13	1722·72	231	0·13	2153·27	260	0·12	1854·50	307	0·16	1199·34	114	0·09	1035·33	51	0·04
October	I	771·37	84	0·11	1689·31	437	0·26	1603·54	160	0·09	1380·49	449	0·32	1103·25	199	0·18	1027·09	101	0·09
	II	389·40	34	0·08	630·03	99	0·16	805·82	47	0·05	511·93	266	0·51	821·97	92	0·11	602·33	7	0·01
November	I	824·22	129	0·15	1698·46	225	0·13	1550·42	133	0·08	1659·44	170	0·10	1580·95	90	0·05	634·09	71	0·11
	II	402·41	66	0·16	1139·38	138	0·12	889·26	132	0·14	895·66	85	0·09	691·73	108	0·15	743·68	100	0·13
				2·006			0·807			0·443			0·738			0·321			0·409
Av. Inf. per sq. in. during the season																			
1935																			
June	II	158·07	1022	6·46	140·08	204	1·45	138·86	296	2·24	181·23	470	2·59	197·51	328	1·61	240·24	132	0·54
July	I	218·31	1705	7·81	265·61	1715	6·46	262·71	899	3·42	293·98	430	1·46	...	...	...	351·94	195	0·55
	II	803·25	1820	2·26	877·13	736	0·83	679·54	928	1·36	950·36	1211	1·27	838·38	874	1·04	960·11	896	0·93
August	I	1252·83	7859	6·27	2478·27	5031	2·03	2274·69	5002	2·19	3022·99	3844	1·26	1998·73	3488	1·74	2203·36	2581	1·17
	II	1034·72	2133	2·06	1608·53	1818	1·13	1778·45	1036	0·51	2062·59	1888	0·90	1457·69	1355	0·09	1539·55	1237	0·80
September	I	1051·63	162	0·16	2912·76	483	0·16	2480·20	640	0·24	2896·26	828	0·28	1083·62	294	0·27	2226·28	615	0·27
	II	980·03	64	0·06	1294·89	110	0·08	1162·33	150	0·12	1269·89	128	0·10	...	...	...	869·47	167	0·19
October	I	337·91	44	0·13	529·03	38	0·06	733·67	84	0·11	744·67	48	0·06	...	...	...	541·71	48	0·08
	II	621·34	113	0·18	976·65	116	0·11	1205·28	133	0·11	1273·75	41	0·03	...	...	...	732·01	91	0·12
Average				2·281			1·368			1·153			0·883			0·950			0·517

TABLE V

Analysis of variance

Variance due to (or S. V.)	1934 D. F.	1934 S. S.	1934 M. S.	1934 F.	1935 D. F.	1935 S. S.	1935 M. S.	1935 F.
ates of observations . .	11	43·1026	3·9184	..	8	79·7477	9·9685	..
arieties	5	23·6057	4·7211	4·545**	4	28·0384	7·0096	4·298**
rror	55	57·1318	1·0388	..	32	52·1935	1·6310	
Total .	71	123·8401	..	..	44	159·9796	..	

Average values of infestation

—	S. E.	Sig. diff.	Moll.	4 F	L. S. S.	289 F	N. T. 43	N. T. 38
934		0·848	2·006	0·807	0·738	0·443	0·409	0·321
935		1·234	2·821	1·368	0·883	1·153	0·517	..

Relative attack of white-fly

(Order of significance)

934 . . .	Moll.	4 F	L. S. S	289 F	N. T. 43	N. T. 38
935 . . .	Moll.	4 F	289 F	L. S. S.	N. T. 43	

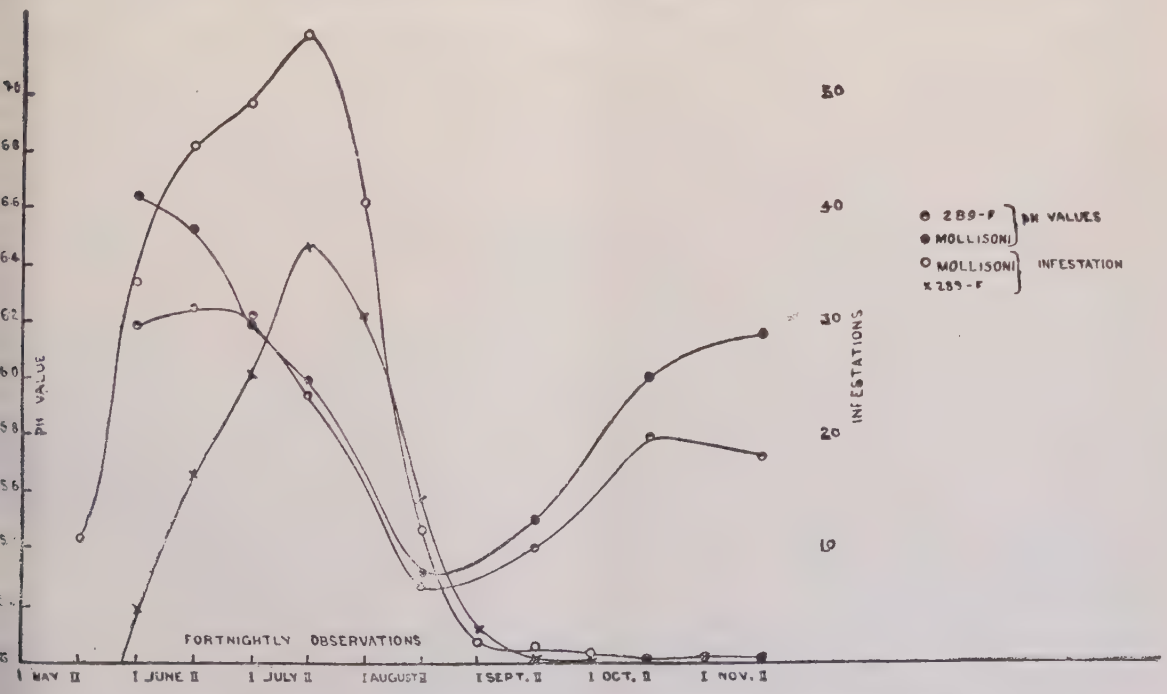

FIG. 3. White-fly infestation and *p*H values of varieties of cotton in 1932

but there was a certain amount of lag and the insect attack did not fall exactly when the *p*H curve went down. This is not contrary to expectation because the nymphs being fixed on the leaves, could not move and it must take some time before the effect of the change in *p*H can be appreciated by the insects feeding on the sap.

During 1933, the incidence of white-fly attack in general was quite insignificant throughout the season and the *p*H values of the leaf sap were correspondingly low. This opens up a fruitful line of attack on this pest. Variations in *p*H might be responsible for relative immunity of varieties and control of seasonal multiplication of certain pests be affected by changing this val Hence the possibility of preventing attack sucking insects through soil treatment.

(2) During 1934 and 1935 preliminary obser tions were made to stu dy if any correlation exist between the incidence of white-fly and the amou of moisture in the leav es of various types of cott The data with regard to the moisture are prese ed in Table VIII, whe reas the relative infestati have been taken into account from Table IV summarized under for tnightly intervals. Of the types under observ ation *mollisoni* had t least percentage of mois ture while 4F had t maximum.

TABLE VI

Range of variations in p*H of different leaves of a cotton plant*

Month	1932		1933	
	289-F	*Mollisoni*	289-F	*Mollisoni*
June	6·28—6·41	6·19—6·90	5·34—5·48	5·30—5·6
July	5·59—6·49	5·79—6·47	5·30—5·55	5·42—5·6
August	5·19—5·31	5·16—5·42	5·25—5·68	5·30—5·8
September	5·25—5·55	5·25—5·95	5·30—5·60	5·12—5·6
October	5·20—7·50	5·40—7·50	5·42—6·29	5·38—6·1
November	5·30—6·95	5·45—7·10	..	..

Because of these variations, the mean of the *p*H values of all the leaves was taken for comparison. These results are given in Table V and the values for 1932 have been plotted in Fig.

TABLE VII

Relative incidence of B. gossypiperda *attack on* mollisoni *and 289F cottons and the* p*H value of the respective cell sap*

Fortnight	1932				1933			
	Mollisoni		289-F		*Mollisoni*		289-F	
	Infestation per sq. in. of leaf area	*p*H value	Infestation per sq. in. of leaf area	*p*H value	Infestation per sq. in. of leaf area	*p*H value	Infestation per sq. in. of leaf area	*p*H va
June I	36·00	6·64	4·67	6·19	8·03	..	1·17	..
II	45·66	6·53	20·36	6·25	1·14	5·41	1·07	5·41
July I	48·19	6·19	25·22	6·22	2·73	5·57	1·01	5·43
II	55·70	5·94	37·45	5·95	1·67	..	0·98	..
August I	39·97	..	35·60	..	0·50	5·65	0·52	5·53
II	9·32	5·32	11·22	5·27	0·35	..	0·10	..
September I	1·72	..	3·06	..	0·28	..	0·16	..
II	1·03	5·50	0·23	5·39	0·32	5·42	0·14	5·4
October I	0·58	..	0·38	..	0·12	..	0·13	..
II	0·30	6·08	0·26	5·80	0·14	5·67	0·09	5·7
November I	0·48	..	0·13	..	0·30	..	0·15	..
II	0·48	6·16	0·20	5·74	0·57	..	0·13	..

TABLE VIII

Relative amount of moisture in the foliage of different varieties of cotton

Variety of cotton	1934				1935				
	Percentage of moisture on				Percentage of moisture on				
	6·VII	20·VII	2·VIII	Average	21·VI	27·VII	13·VIII	6·IX	Average
Mollisoni	71·7	75·2	73·4	73·4	78·0	77·1	75·6	72·7	75·9
F	79·2	79·9	80·2	79·8	83·0	81·6	80·2	76·9	80·4
89F	79·0	77·8	80·6	79·1	83·4	80·6	79·7	78·1	80·5
S. S.	74·1	79·8	78·9	77·6	82·1	78·7	77·2	75·1	78·3
T. 38	78·2	79·6	79·7	79·2	82·6	79·3	77·9	75·3	78·8
T. 43	78·2	79·5	78·2	78·6	82·5	80·4	79·5	75·2	79·4

These observations have not shown very strict elationship between the percentage of moisture nd the white-fly attack on different varieties. he only conclusive statement that can be offered n this connection is, that *mollisoni* with lowest ercentage of moisture was highly infested. These esults support the observations in the fields in so ar as the restricted irr gations have yielded com-aratively higher white-fly attack as is shown elow.

INCIDENCE OF WHITE-FLY ATTACK IN RELATION TO THE AMOUNT OF WATER APPLIED TO COTTON CROP IN THE FIELDS

Insect behaviour towards crops depends on arious factors and soil moisture may be one of hem. Mumford [1925] put forth an hypothesis hat a disturbed water content from whatever ause rendered the cotton plant more susceptible o the attack of sap feeding insect pests such as hrips. In California thrips have never been found n large numbers on cotton plants receiving opti-mum water supply whereas those suffering from hortage of water have been found to be more ttractive. This statement also receives support rom Bedford [1921] with his observations on *Heliothrips indicus* Bagnell, on Egyptian cotton in he Sudan. Withycomb [1926] has also found s true in the case of sugarcane frog hopper, *Tomaspis saccharina* Dist. Wardle [1927] states hat the plants receiving excessive water supply ave a relatively lower infestation of *Thrips tabaci* ind than those receiving sufficient supply, while, hose receiving the minimum water supply have a elatively higher attack than those receiving nor-al irrigation. Lees [1926], on the other hand, aintains that heavy irrigation and heavy rainfall esulted in increased susceptibility to berseem phis, *Trifolium alexandrium*. It is obvious, therefore, that different insects behave differently in this respect.

To determine the behaviour of *B. gossypiperda*, however, observations were carried out in the watering experimental plots of the Cotton Research Botanist, at Risalewala. Seven to nine types differentiated into 5-6 sets according to the number of irrigations, were under observation. The range of variation in the number of irrigations in the respective sets was 3-7 in 1931, 4-10 in 1932, 3-7 in 1933 and 4-9 in 1934. The total amount of water applied to various sets, therefore, varied from 8·96 to 20·83 in.; 18·81 to 36·05 in.; 8·99 to 26·90 in.; and 12·01 to 26·92 in. respectively. Relative incidence of *B. gossypiperda* in different sets was estimated at fortnightly intervals. Average number of immature stages of the pest, per square inch of leaf area, was worked out from 2-4 replications of the plots under each treatment and the data are summarized in Table IX.

The data presented above have shown that type IV which received the largest number of irrigations and consequently, the maximum amount of water throughout these investigations had, on an average, the lowest white-fly attack. On the other hand, types III during 1931 and 1932, VII during 1933 and III, VIII and IX during 1934, which received restricted irrigations and therefore the minimum supply of water, were comparatively severely infested (Fig. 4). Although the white-fly infestation in general w s extremely low during 1933 and 1934, as compared to that in the first two years, still the trend of the relative attack in the respective types was practically the same. Thus it may be presumed that abundant water supply to cotton crop lowers the white-fly infestation to a considerable extent whereas reduced water supply increases the susceptibility for attack. The data were analysed statistically and their results are given below:

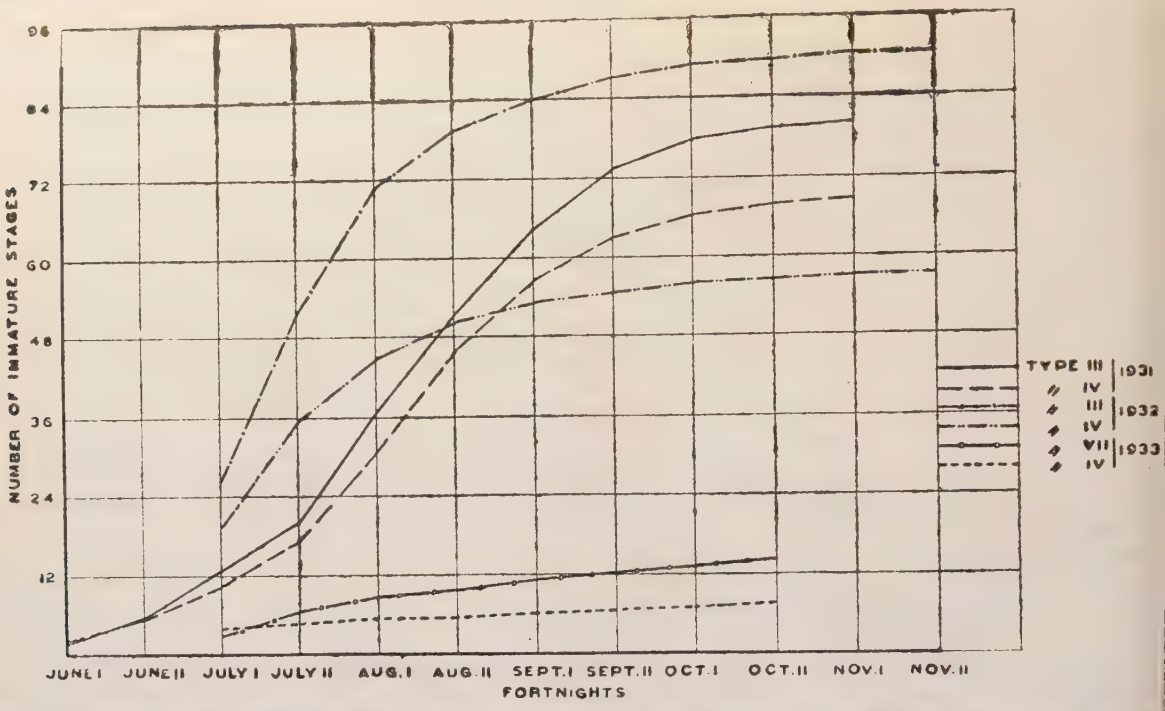

FIG. 4. Comparative infestation of *B. gossypiperda* in relation to the maximum (Type IV) and minimum (Types and VII) number of irrigations applied to cotton crop —1931-33

TABLE IX

Relative incidence of B. gossypiperda *in relation to the amount of water applied in the fields—1931-3*

Year	Type No.	No. of irrigations given	Total amount of water applied (acre in.)	Total leaf area examined (sq. in.)	Average infestation per sq.
1931	IV	7	20·83	792 Observations on each leaf were made within an area of 1 sq. in.	6·28
	I & VI	6	17·85	1584	6·66
	VII	5	15·14	792	6·97
	II & V	4	11·75	1584	6·72
	III	3	8·96	792	7·25
1932	IV	10	36·05	5688·81	4·77
	VI	8	29·81	5122·19	6·18
	I & V	7	26·87	11167·50	6·34
	VII	6	23·95	5242·78	6·62
	II	5	21·09	5650·96	7·80
	III	4	18·82	5490·00	7·40
1933	IV	7	26·90	4076·05	0·68
	I	6	18·05	3988·06	1·05
	VI	5	14·82	4297·45	0·93
	II, III, V	4	12·03	12160·87	1·26
	VII	3	8·99	4203·52	1·55
1934	IV	9	26·92	3586·02	0·67
	VI	8	24·00	3480·64	0·95
	V	7	20·96	3493·01	0·84
	I, VII	6	17·92	7054·05	0·70
	II	5	15·06	3655·33	0·86
	III, VIII, IX	4	12·01	10606·09	1·22

The correlations between the amount of water and the incidence of attack as given in Table IX were worked out for all the four years and the values obtained were —0·860 ; —0·958 ; —0·906; and —0·653 for N = 5 ; 6 ; 5 and 6 for the years 1931, 32, 33 and 1934 respectively. The correlation in all the cases was high and negative being significant in 1932 and 1933. This shows that an increased amount of water depressed the white-fly attack. Since a cultivator understands more in terms of the number of irrigations than the amount of water applied to his crop, therefore, the four types of irrigations, i.e. 4, 5, 6, and 7 which were common in all the years were compared and the average infestation per sq. in. ranged as 4·15, 4·14, 3·76 and 3·53 with a standard error of ±0·153. The trend was linear and the number of irrigations on the whole differed significantly, there being no significant difference between 4, 5, and 6 irrigations and between 6 and 7. From this it may easily be concluded that 6 or 7 irrigations are needed in order to suppress the white-fly attack significantly.

Incidence of white-fly attack under different conditions of cultivation

A. *Pit and line sown.* This experiment was conducted during 1934, by the Deputy Director of Agriculture, Lyallpur. Cotton was sown in a few plots in lines as usual while in others alternating to those, it was sown in pits which were 5 ft. apart from each other and were filled up with farmyard manure before sowing. Each of these pits had a single cotton plant and the rest of the agricultural operations were uniform in both the sets. The plants grown in pits were very bushy evidently because of the larger space and excessive manure. The relative white-fly attack was worked out weekly on the respective sets and the crop sown in pits showed, on an average, comparatively lower attack as shown in Table X.

Table X

Relative infestation of B. gossypiperda *on crop sown in pits and in lines*

Time—Fortnightly	Pit sown		Line sown	
	Leaf area examined	Average infestation per sq. in.	Leaf area examined	Average infestation per sq. in.
July I	526·40	0·78	500·90	4·00
II	396·10	2·09	489·52	6·40
August I	1066·69	0·72	1095·12	1·70
II	948·89	0·27	933·05	0·71
September I	1036·10	0·28	966·75	0·38
II	467·29	0·05	529·69	0·16
October I	831·03	0·14	724·40	0·29
II	760·65	0·22	802·09	0 36

REFERENCES

Afzal Husain, M. and Trehan, K. N. (1933). *Indian J. agric. Sci.* **3**, 701-53

Afzal Husain, M., Trehan, K. N. and Varma, P. M. (1936). *Indian J. agric. Sci.* **6**, 873-903

Bedford (1921). *Wellcome Trop. Res. Lab. Khartaum. Ent. Sec. Bull.* **18**

Gustafson, F. G. (1924). *Amer. J. Bot.* **11**, 1-6

Hass, A. R. C. (1920). *Soil Sci.* **9**, 341

Jakson, F. K. (1934). *Emp. Cot. Grow. Corp. 2nd Conf., London*, **197**

Lees, A. H. (1926). *Ann. App. Bio.* **13**, 506

Lloyd, L. L. (1922). *Ann. App. Bio.* **9**, 1-32

Mukerji, S. K. (1928). *Proc. Linn. Soc.* **140**, 3-5

Mumford, E. P. (1930). *Nature*, **125**, 482

Wardle (1927). *Ann. App. Bio.* **14**, 482

Withycombe, C. L. (1926). *Ann. App. Bio.* **13**, 64

STUDIES IN SOIL DISPERSION

I. DISPERSION OF SOILS BY MECHANICAL METHODS

By Amar Nath Puri, Prabhu Dyal and Balwant Rai, Punjab University Institute of Chemistry, Lahore

(Received for publication on 19 January 1943)

Mechanical methods of soil dispersion were largely used in the beaker method of mechanical analysis of soils, where maximum dispersion in single operation is not necessary. The advent of the pipette methods brought into prominence the entire question of soil dispersion. It was soon realized that the mechanical methods failed to bring about complete dispersion. The use of chemicals not only ensured maximum dispersion, but the technique could be standardized much more efficiently than was the case with mechanical methods.

Among the purely mechanical methods of dispersion one of the oldest is boiling which is probably still used in certain laboratories and its use in electrolyte free suspensions may be justified. Comparatively recently Nostitz [1926] endeavoured to obtain the effect of 'cold boiling' by drawing air through the suspension and thus obviate the objectionable features of heating. Simple rubbing in water with a stiff brush or rubber pestle was another early procedure used by Beam [1911]. Whittles [1924] used a vibrating machine to disperse soil samples and Olmstead [1931] used supersonic waves for the purpose. The supersonic vibrations were produced by a piezo-electric quartz crystal immersed in an oil bath. The energy was transmitted through the oil into an Erlenmeyer flask containing a water suspension of the soil. The arrangement, however, is far too costly to justify its use for routine purposes especially as the results are practically the same as those obtained by rubbing with a rubber pestle. Bouyoucos [1927] used an electric drink mixer to disperse his samples. This procedure was slightly modified by Baver [1928].

The use of chemicals such as sodium carbonate or ammonia to aid dispersion by shaking was advocated by Briggs, Martin, and Pearce as early as 1904. Although the nature of the chemicals used has differed in the hands of different workers, this simple procedure still remains the most widely used standard method of dispersion. The advisability of using chemicals has always been the subject of heated discussion and opinion is still divided on this question. Several workers have passed judgment in favour of one or the other method. The main difficulty has been the lack of an absolute standard for reference. Modern physico-chemical methods of dispersion aim at maximum dispersion as evidenced by the highest yield of clay and thus can provide an absolute standard for comparison. It has been shown by Puri and Manohar Lal [1938] that provided the only exchangeable ion in a soil is Na or Li and its *p*H value not less than 10·8 its dispersion is at its maximum, and the yield of clay the highest. It is quite immaterial how this condition is brought about experimentally. For instance, we can directly shake it with the requisite amount of NaOH or LiOH, if it is a hydrogen soil; on the other hand, if it is a Ca-soil, we can convert it into a H-soil by dil. HCl treatment and then shake it with NaOH or LiOH [Puri and Amin, 1928], or we can precipitate the exchangeable Ca by treatment with ammonium carbonate [Puri, 1935] or sodium carbonate or oxalate [Puri, 1936] or we can replace the exchangeable Ca by Na by treatment with NaCl [Puri, 1929]. Provided that in every case we make sure that the soil has been finally brought to *p*H 10·8, the results are the same whatever method is used. This result is very important and should go a long way in providing a fundamental basis for the large number of apparently arbitrary methods of dispersing soils for mechanical analysis of soils. This generalization by defining the final stage of dispersion will greatly help in overcoming the natural reluctance of workers, versed in one method to adopt another. Since this final stage can be brought about in several ways, it is immaterial which method we use as long as we remember the conditions under which maximum dispersion is obtained. Having enunciated this fundamental principle, we can examine the purely mechanical methods of dispersion with greater confidence. It must be remembered that the dispersion of soil colloids is largely a question of overcoming the cohesion between the particles. Physico-chemically it is brought about in a medium of *p*H 10·8 with Na or Li ions when the cohesion under water is minimum. Physically the choice must fall on one or more of the half a dozen methods referred to in the foregoing.

Experimental

The choice of a H-soil for the preliminary experiment is obvious in view of the fact that it is the starting point for the gradual introduction

f bases. Not only it is the most important asic material for all soil studies, but its use is articularly appropriate in this case as the nternal cohesion is probably the highest and a mechanical treatment is successful in this ase, the efficiency of the method for all types of oils will be assumed. Besides, a H-soil is often equired at maximum dispersion for several hysico-chemical measurements. This object can e accomplished by converting it first into a a-soil at *p*H 10·8, and then reconverting it to a H-soil without allowing it to dry. This proce-ure is tedious and it is not certain if this double reatment does not produce any material changes n the soil. A straight-forward mechanical dis-ersion would be far superior for fundamental udies of this nature. For comparing the arious mechanical methods of dispersion such reatments which require elaborate mechanical ontrivances were left out of consideration, for was felt that unless a physical method could be ade at least as simple as the admittedly efficient hemical treatments, it would not find favour enerally from the practical point of view.

The following methods were tried :

(*1*) Boiling, both 'cold' and hot and with sand.

(*2*) Rubbing with rubber pestle.

(*3*) Simple shaking in a mechanical shaker with and without rubber balls or sand.

These are dealt with under separate heads. black cotton soil was used in the first instance. was freed from bases by the usual *0·05 N*. HCl reatment and air dried. The maximum clay ercentage in the soil was 55.

) *Boiling*

Boiling was done for varying lengths of time ith varying amounts of water. The technique r 'cold boiling' constituted in drawing a cur-nt of air through a sintered glass Buchner unnel. The results are given in Table I.

It will be seen that boiling does not seem to e an efficient method of dispersion. Even the ghest clay, i.e. 37·4 per cent obtained by 4 ours' boiling is much below the maximum of 5 per cent which this soil contains. It is sur-rising that the so-called 'cold boiling' is the ast helpful. It was believed that the presence f sand might help in the breaking up of the ggregates. It seems that though this gives a ightly higher yield of clay the difference is not ery significant.

) *Rubbing with rubber pestle*

Rubber pestle was the usual rubber bung tached to a stout glass rod. Rubbing with the nd besides being tiring is not effective as will

TABLE I

Dispersion of a H-soil (containing 55 per cent of clay) by boiling

(10 gm. of the soil taken)

..	Clay per-cent	Remarks
Boiling for 30 min. with 100 c.c. of H_2O . . .	21·5	
Boiling for 30 min. with 200 c.c. of H_2O . .	20·4	Effect of volume is thus nil
Boiling for 30 min. with 300 c.c. of H_2O . .	22·1	
Boiling for 30 min. with 400 c.c. of H_2O . .	22·1	
Boiling for 15 min. with 200 c.c. of H_2O . .	18·5	
Boiling for 1 hour with 200 c.c. of H_2O . .	25·3	
Boiling for 2 hours with 200 c.c. of H_2O . .	32·1	
Boiling for 4 hours with 200 c.c. of H_2O . .	36·2	
Boiling for 4 hours with sand	37·4	
'Cold boiling' for 30 min. with 50 c.c. of water .	3·6	As compared to boiling dispersion is very little
'Cold boiling' for 30 min. with 25 c.c. of water .	3·5	

be seen from Table II. A rubber pestle attached to a motor that was made to rotate in an agate mortar held in the hand and pressed lightly against the pestle proved very effective. The maximum clay was obtained in half an hour.

TABLE II

Dispersion of a H-soil (containing 55 per cent of clay) by rubbing with a rubber pestle

(10 gm. of the soil was taken)

	Clay per cent (0·002 mm.)
Rubbed in an agate mortar with the rubber pestle by hand with 10 c.c. of water for	
5 minutes	6·0
10 minutes	16·0
15 minutes	14·2
30 minutes	24·6
Rubbed in an agate mortar with a mechanically rotated rubber pestle with 10 c.c. of water for	
5 minutes	38·0
10 minutes	44·8
15 minutes	47·2
20 minutes	52·2
30 minutes	55·6
Rubbed for 30 minutes as above with	
20 c.c. of water	48·6
30 c.c. of water	44·9
40 c.c. of water	42·8

It will also be seen that the amount of water used has an important bearing on the success of this method. When the amount of water is increased from 1 : 1 ratio the soil particles have a tendency to float and thus escape the grinding action of the pestle.

(3) Shaking in a mechanical shaker

A mechanical shaker is the simplest and most widely used contrivance for the dispersion of soil. Its effectiveness can be enhanced by the addition of rubber balls or sand to the suspension. Shaking the suspension with sand gave the highest yield of clay as will be seen from Table III.

TABLE III

Dispersion of a H-soil (containing 55 per cent of clay) by mechanical shaking

(10 gm. of the soil was taken)

Time of shaking	Addition to suspension	Clay per cent
24 hours	Nil	22·9
24 hours	10 Rubber balls . . .	15·3
24 hours	20 rubber balls . . .	18·6
24 hours	50 gm. of coarse sand . .	52·8
24 hours	50 gm. of fine sand . .	42·1

Maximum dispersion with sand is attained by shaking for 24 hours using a soil-sand ratio of 1 : 5. Neither the temperature nor the volume of water used (which could be raised from 25 c.c. to 300 c.c.) had any effect on rate of dispersion or the maximum dispersion obtained.

Results obtained with a drink mixer and simple shaking were of lower order and these methods were consequently not used except in the preliminary work. The most effective method, namely, shaking with sand, was examined in detail as it presented attractive possibilities. It requires practically no attention during the time the suspension is being shaken, and beyond the addition of the requisite amount of sand there is no preliminary treatment involved. Sand used for the purpose was of the coarse white variety having particles of about 1·5 mm. diameter. It was easily recovered after dispersion, by passing the suspension through a sieve of 1 mm. mesh, and used over and over again.

COMPARISON OF THE SAND METHOD WITH OTHER STANDARD METHODS

In view of the importance of these results in evolving, for practical use, a purely mechanical method of dispersion, and in view of the fact th the chemical methods are almost universal used in soil laboratories, it became imperati that the sand method should be compared wi the chemical methods of dispersion. For th purpose 157 soils were used. These soils ha been collected from different parts of India a represented practically all types. Also 59 H-soi were compared by the two methods. The resul are given in Tables IV and V. The results f convenience of space are tabulated as differen between the two methods against the numb of soils showing difference of that order. plus sign indicates a higher value than the chem cal method and the negative value a lower resul

TABLE IV

Comparison of clay contents obtained by dispersi natural soils with the proposed sand method and the chemical method

Difference between the clay per cent by the two methods	Number of soils show ing difference of this order	
	+	—
0·0 to 1·0 . . .	33	18
1·1 to 2·0 . . .	13	14
2·1 to 3·0 . . .	19	10
3·1 to 4·0 . . .	13	9
4·1 to 5·0 . . .	10	7
5·1 to 6·0 . . .	1	*Nil*
6·1 to 7·0 . . .	2	1
7·1 to 8·0 . . .	*Nil*	*Nil*
8·1 to 9·0 . . .	*Nil*	*Nil*
9·1 to 10·0 . . .	*Nil*	*Nil*
10·1 to 15·0 . . .	3	*Nil*
15·1 to 20·0 . . .	3	*Nil*
20·1 to 25·0 . . .	1	*Nil*

For hydrogen soils the chemical method used the addition of sufficient NaOH to bring the of the suspension to 10·8 and for natural s Na_2CO_3-NaOH [Puri, 1936] method of dispers was employed. The *p*H in this case was brought to 10·8. The latter method may regarded as the least drastic of all the chem methods and therefore most appropriate comparison with a purely mechanical met The results revealed the following facts :

TABLE V

mparison of clay contents obtained by dispersing H-soils with the proposed sand method and the chemical method

Difference between the clay per cent by the two methods	Number of soils showing difference of this order	
	+	—
0·0 to 1·0 . . .	2	4
1·1 to 2·0 . . .	2	5
2·1 to 3·0 . . .	4	1
3·1 to 4·0 . . .	*Nil*	2
4·1 to 5·0 . . .	2	3
5·1 to 6·0 . . .	3	2
6·1 to 7·0 . . .	5	1
7·1 to 8·0 . . .	3	*Nil*
8·1 to 9·0 . . .	5	*Nil*
9·1 to 10·0 . . .	4	1
10·1 to 15·0 . . .	4	4
15·1 to 20·0 . . .	*Nil*	*Nil*
20·1 to 25·0 . . .	1	1

1. The majority of natural soils (150) gave aximum dispersion with the sand method and ıe results agreed with the Na_2CO_3 method.

2. Some natural soils (7 out of 157) gave higher ılues with the sand method as compared to the a_2CO_3 method.

All these seven soils, though from vastly differ-ıt localities, belonged to one type, namely ıales. The low values for these soils in the ıemical method were due to the failure of the a_2CO_3 method to bring about complete disper-ɔn. When these soils were acid treated and ıen shaken with NaOH at *p*H 10·8 they dis-ɛrsed completely and the values agreed with ıe sand method.

3. Only one natural soil gave a higher value by 6 per cent with the Na_2CO_3 method.

4. Six natural soils showed flocculation when ıe volume was made up after shaking with sand. /hen the soil had settled down and the clear ıpernatent liquid was poured off and replaced y fresh distilled water the suspension was ;abilized. The flocculation in these soils was due to salts and when these were removed by a preliminary leaching with water, the dispersion was complete with sand.

5. Two natural soils persisted in being flocculated after dispersion with sand. No amount of preliminary leaching with water improved matters though a small amount of alkali stabilized the suspension and the yield of clay was maximum. These soils had low *p*H value and contained only Ca as the exchangeable base. On removing the exchangeable Ca by acid treatment the soil could be dispersed completely by the sand method. The dispersion was even slightly enhanced by the addition of $Ca(OH)_2$ but when the amount of $Ca(OH)_2$ was increased to the quantity originally present in the soil flocculation took place. It appears therefore that these soils contain exchangeable Ca just about the quantity required for flocculation which has either to be removed or rendered inactive by the addition of Na_2CO_3.

6. The agreement between the chemical and mechanical methods was not so close in the case of H-soils (Tabel V) as in the case of natural soils. This is evidently due to the fact that an acid treated soil has got very unfavourable *p*H value for the stabilization of the soil colloids and the difference between the reaction of the alkali treated and untreated soil is very great.

The results on the whole would leave no doubt that the sand method is an effective means of dispersing natural soils. A number of natural soils dispersed by Na_2CO_3 method and the sand method were subjected to complete mechanical analysis and the summation curves obtained by the two methods were found to be almost identical. There is thus no break down of the coarser fractions into particles that did not originally exist in the soil. The remarkable agreement between the mechanical and chemical methods of dispersion shows that neither the one nor the other is too drastic and that both give the size distribution of primary particles as they exist in soils.

As already mentioned chemical dispersion of a soil is not complete until a *p*H value of 10·8 is reached. At this *p*H the soil does not require any mechanical shaking. However, when chemical dispersion is aided by mechanical dispersion, the maximum dispersion is obtained at a lower *p*H value than otherwise. In other words the effect of chemical and mechanical dispersion becomes additive. This will be clear from Table VI in which the dispersion of a H-soil to which increasing amounts of alkalies have been added was completed with and without shaking with sand.

TABLE VI

Effect of combining chemical and mechanical methods of dispersion, P. C. 13 H-soil per cent clay (< ·002 mm.)

Quantity of N/10 NaOH added to 10 gm. of soil in c.c.	No shaking with sand	Shaking with sand for 2 hours	Shaking with sand for 24 hours
0	1·2	21·0	54·2
3	4·0	29·5	55·5
5	6·6	33·1	55·5
10	13·2	34·0	55·5
15	18·8	37·5	55·8
20	21·4	40·0	55·0
30	28·5	44·7	55·4
40	37·5	49·5	55·5
50	49·5	53·0	56·0
60	55·0	55·2	55·5

The efficiency of the sand method for dispersing soils led to the speculation that this treatment may be too drastic for some soils so instead of breaking up the aggregates, some of the coarse primary particles as well might get broken up. Information on this point could be gathered by shaking a soil with sand for a much longer period than the prescribed 24 hours and to see if there is any tendency for the gradual increase of fine particles at the expense of the larger ones on continuous shaking. On shaking P.C. 13 soil for varying periods, up to a maximum of seven days, it was found that there was no increase in any fraction by shaking for longer periods and the percentages of various fractions obtained on seven days shaking were exactly the same as those obtained on 24 hours shaking The sand method therefore is not too drastic to break up primary particles.

The sand method, as pointed out before, presents the possibility of obtaining normally undispersed H-soils in a dispersed condition. The soil thus dispersed no longer remains so if it is dried. There is no known method by which a dispersed H-soil could be preserved in the dry state so that on coming in contact with water it might give a highly dispersed suspension. The fact that softer crumbs are produced when a soil wetted with alcohol is dried, led to the possibility of dispersing soil in alcohol in the first instance. The filtration of the alcohol dispersed soil is rapid and on drying it falls to a powder. It was found, however, that although the soil could be dispersed as in the case of water by shaking with alcohol, and there was also no difficulty in filtration but on drying it could not be redispersed in water. In order to test the possibility of this state of affairs being due the traces of water present in alcohol attem were made to exclude water completely dur the final drying. The soil was dispersed alcohol with sand, filtered and washed w alcohol, then with benzene and finally w ether. It was then dried in a current of air and kept in a desiccator until redispersed water. Even with this treatment the soil co not be kept in a fully dispersed condition in dry state though the dispersion was much grea than when water saturated dispersed soil w dried.

SUMMARY

Of the purely mechanical methods of dispers soils, shaking for 24 hours with coarse sand the most effective. The diameter of s particles is one to two millimeters and the amo used is five times the weight of soil.

REFERENCES

Baver, L. D. (1928). Mechanical dispersion as an a the chemical study of soils. *J. Amer. Soc. Agron.* 403-10

Beam, W. (1911). The mechanical analysis of acid *Expt. Sta. Record.* **25**, 513

Bouyoucos, G. J., (1927). The hydrometer meth a new and rapid method for determining coll contents of soils. *Soil Sci.* **23**, 319-30

Briggs, L. J., Martin, F. D. and Pearce, J. R. (1 The centrifugal method of mechanical soil anal *U. S. Deptt. Agric. Bureau of Soils, Bull.* **24**

Nostitz, A. Von. (1926). Preparation of a soil for pr cal suspension analysis. *Soil Sci.* **2**, 305-8

Olmstead, L. B. (1931). Dispersion of soils by a su sonic method. *J. Agric. Res.* **42**, 841-2

Puri, A. N. and Amin, B. M. (1928). A comparative s of the methods of preparation of the soils for me nical analysis with a note on the pipette met *Agric. Res. Instt. Pusa, Bull. No.* **175**

Puri, A. N. (1929). A new method of dispersing for mechanical analysis. *Mem. Dept. Agric. I Chem. Ser.*, **10**, 209-20

Puri, A. N. (1935). The ammonium carbonate meth dispersing soils for mechanical analysis. *Soil Sci* 263-70

Puri, A. N. (1936). Dispersion of soil for mechan analysis by Na_2CO_3 or $Na_2C_2O_4$ treatment. *Soil* **42**, 267-72

Puri, A. N. and Manohar Lal (1938). Dispersion stability of soil colloids, Part I. Auto-disinte tion. *Pb. Irrig. Res. Instt. Res. Pub.* **4**, No. 10

Whitles, C. L. (1924). Method for the disintegratio soil aggregates and the preparation of soil suspens *J. agric. Sci.* **14**, 346-69

STUDY OF THE FERTILIZING VALUE OF THE SILTS CARRIED IN SUSPENSION BY THE RIVERS OF THE PUNJAB

R. C. Hoon, M.Sc., Ph.D., and C. L. Dhawan, M.Sc., Ph.D., Irrigation Research Institute, Lahore

(Received for publication on 4 October 1943)

E investigation described in this paper had origin in a discussion which took place at the terlogging Conference in Lahore in 1935. It s mentioned at that Conference that in order to vent the further rise of bed levels of canals silt luders were being fitted to the heads of some als and distributories. Fears were expressed t the exclusion of this silt might reduce the posed fertilizing properties of water. In this er connection the view of the zamindars, who ard the silt carried by the river Ravi to be of ater fertilizing value than the silt in other ers of the Punjab, was also put forth.

The utility of the excluded silt

The objections to the deposition of silt in the bed a channel are the reduction in capacity of the al, the raising of the full supply level and the sequent increase in seepage and the increased t of maintenance of the banks which becomes essary. Silt exclusion at the head of a canal is igned to deal only with that portion of the silt t is likely to form bed silt in some part of the tem. It is, in fact, impossible to exclude much he finer fractions of the silt as this tends to be nly distributed throughout the depth of water channel and not concentrated in the bottom er as is the case with the coarser fractions.

The size of the particles forming bed silt in the main lines, branches and distributories of the Punjab canal system usually exceeds 0·05 mm. in diameter and is frequently situated in the range 0·05 mm. to 0·6 mm. in diameter. A survey of the watercourses to determine the size of the silt particles deposited in them had brought out, on the other hand, that almost all the particles less than 0·01 mm. in diameter remain in suspension and reach the fields. A comparison of the mechanical analysis of the sediment deposited in special tank from water of the river Nile and the mud from channel leading to sedimentation basins of Giza water service is given in Table I and confirms the observations made above. According to the International Classification of particle sizes the bed silt in the Punjab canals belongs to the fine and coarse sand fractions. While these fractions may be regarded as the frame work of the soil, little importance may be attached to them as sources of plant food. The exclusion from a canal system of material likely to form bed silt can have no effect on the fertilizing value of the silt laden water which reaches the fields. From the agricultural point of view, therefore, the examination of the fertilizing properties of silt particles below 0·01 mm. in diameter is more important.

Table I

Mechanical analyses of Nile silt

(By A. D. Hill, Director, Rothamsted Experimental Station)*

	Water from river, sedimented in special tank		Mud from channel leading to sedimentation basins of Giza Water Service	
	Dried at 100° per cent	Ignited per cent	Dried at 100° per cent	Ignited per cent
ained by sieve above 0·2 mm.	..	..	..	..
sediment 0·2—0·04 mm.	0·60	0·58	10·25	10·05
,, 0·04—0·01 mm.	8·17	7·82	38·02	36·90
,, 0·01—0·004 mm.	17·53	16·62	10·33	9·54
,, 0·004—0·002 mm.	10·40	9·15	7·08	5·85
0·002 mm.	50·24	42·92	26·64	22·33
s on solution	2·34	2·34	5·27	5·27
sture	8·58	8·58	4·64	4·64
s on ignition	..	10·27	..	7·06
	97·86	98·28	102·23	101·64

* Taken from the *Egyptian Irrigation* by Willcock & Craig

Nature of silts brought down by the Punjab rivers

In the Punjab, the year can be divided into three periods with reference to both the type and quantity of silt in suspension in the river waters. The rivers commence to rise in March due to the melting of snow on the high hills. With this rise in the rivers, a grey silt is brought down to the plains. The production of this grey silt is most probably due to the physical weathering of the rock, and therefore, it consists of unchanged rock material in a fine state of sub-division. The grey silt is a potential source of fertilizing material which may be rendered available when the silt is subjected to chemical weathering in the plains.

When the rain falls in the hills during the monsoon period the character of the silt in the rivers changes. The run-off from the lower hills causes erosion of the soil and as a result the silt in the rivers has a red appearance. The silt in suspension in the rivers at this period, therefore, consists of a mixture of the grey silt derived from the high hills and soil eroded from the lower hills as the results of the rainfall. It might be expected that the silt in this period would contain more available fertilizing matter than in the pre-monsoon period, since a portion of the material has already been subjected to chemical weathering of the lower hills. On the other hand, since the silt is being transported in water, the available fertilizing constituents may go into solution and only the residue consisting of unweathered rock would reach the fields.

After the monsoon period the grey silt persists for a time but by the middle of November the water becomes clear and generally remains so until the following March. Freshets due to winter rains may occur during this period when a red silt derived from the soils of the lower hills comes in suspension.

Experimental

As there are three silt periods into which the year can be divided, it was decided to sample the silts in suspension in the rivers before, during and after the monsoons. Samples of silt in suspension were collected at the following sites on the various rivers over a period of two years 1935-36 and 1936-37:

(*i*) River Sutlej at Rupar
(*ii*) River Beas at Mandi
(*iii*) River Ravi at Madhopur
(*iv*) River Chenab at Marala
(*v*) River Jhelum at Rasul
(*vi*) River Indus at Ghazighat

The silts were analysed for the following:

(a) The mechanical analysis was done by th usual method.
(b) The total phosphate, potash and sod contents in the HCl extract were determine according to the method adopted by th Agricultural Education Association.
(c) The available phosphate content was don by the CO_2 extraction method [Puri an Asghar, 1936].
(d) The total nitrogen content was determin ed by the method proposed by Bal [1935].
(e) The calcium carbonate content was dete mined by the method proposed by Pu [1931].
(f) The *p*H values of the 1:5 suspensions wer determined by the glass electrode [Hoo and Taylor 1931].
(g) The exchangeable bases were determine by the usual methods. The results of an lyses are given in Tables II-V.

Discussion of results of analyses

(a) *Mechanical analysis*

As had been pointed out in section 2 above, t clay and fine silt only reach the fields during ir gation and therefore these fractions merit conside ation. It will be seen from the results that t Indus and the Sutlej silts contain much hig proportions of silt and clay than those taken fro the other rivers. The Jhelum during the monsoo period has a high content of silt and clay whi indicates considerable soil erosion in its catchme area. The catchment areas of the Beas and Ra are small, which probably accounts for the sma amounts of clay and silt in the monsoon perio in these rivers. A further difference distinguis ing these rivers, from the remainders, at t sampling sites is the velocity of the water. Th Ravi and Beas at the sampling sites have bould beds, the velocity of the water is high and cons quently the amount of coarser material in suspe sion is high. The sampling sites on the Sutl and Indus are well outside the catchment areas an the water velocities relatively low. The coars material will have been deposited upstream the sampling sites which would lead to an i crease in the percentage of the finer fraction The Chenab at Marala appears to have a lo content of the finer fractions at all seasons. Th may be due to the short tributaries from th Jammu hills which enter the river just abov Marala and bring coarse material with the

From the physical point of view, therefore, would be expected that the plains irrigated fro the Sutlej and Indus would tend to become heavi as regards soil type and that there would

Table II

Analytical results of silt samples collected during the year 1935-36

Name of river	Name of site	Time of taking silt sample with reference to the rainy period	Per cent $CaCO_3$ content (on complete silt collected at site)	*p*H	Mechanical analysis Results expressed on air-dry basis)					†Clay as per cent fraction of the total 0·01 mm. particles in the silt sample	†† Per cent $CaCO_3$ content in the portion of silt reaching the field
					Sand >0·2	Fine sand from 0·2—0·02	Silt particles between 0·02 & 0·01	*Fine silt particles between 0·01 & 0·002	*Clay below 0·002 mm.		
1	2	3	4	5	6	7	8	9	10	11	12
tlej . .	Rupur . .	Before .	20·25	8·64	1·52	30·74	12·85	25·50	12·65	33·16	34·68
		During .	11·25	8·59	2·55	55·79	15·63	12·68	5·55	30·44	38·16
		After . .	6·50	8·40	21·68	43·25	11·23	10·65	3·20	23·10	31·93
eas . .	Mandi (plain) .	Before .	1·50	8·35	1·72	65·98	12·15	10·88	4·80	30·61	8·73
		During .	1·50	8·42	7·42	69·92	12·23	7·18	2·80	28·06	13·07
		After . .	1·50	8·57	1·31	75·39	10·75	6·23	2·93	32·00	14·07
avi . .	Madhopur . .	Before .	Nil	7·83	...	...	...	...	1·20	...	...
		During .	0·50	7·57	27·07	52·36	10·88	4·85	1·88	27·94	6·92
		After . .	0·50	7·53	25·28	46·65	21·90	6·30	1·30	17·11	6·17
henab . .	Marala . .	Before .	2·0	9·12	21·11	64·86	6·25	1·10	1·45	56·88	43·95
		During .	2·38	8·22	0·65	50·94	16·45	17·63	9·90	35·96	7·96
		After . .	1·00	7·46	...	...	...	...	1·33	...	...
helum . .	Rasul. . .	Before .	8·88	8·52	0·85	48·23	22·65	12·90	4·75	26·91	33·48
		During .	7·25	8·26	0·20	20·11	23·30	37·75	12·80	25·32	12·54
		After . .	8·50	8·41	6·0	46·20	21·68	13·65	4·05	22·88	32·44
dus . .	Ghazighat . .	Before .	8·00	8·36	0·51	30·62	17·03	24·48	19·05	43·76	15·53
		During .	9·25	8·36	0·28	29·61	17·50	25·30	17·10	40·33	17·91
		After . .	10·50	8·50	...	...	...	...	28·28	...	...

* Columns 9 and 10 : The fractions of the suspended silt that actually reaches the field.

† Column 11 : $\frac{\text{Per cent clay (column 10) x 100}}{\text{Per cent clay (column 10) + per cent fine silt (column 9)}}$

†† Column 12 : The $CaCO_3$ is in a fine state and reaches the field along with particles of silt ranging from 0·01 mm. downwards. he per cent calcium carbonate in column (4) is determined on the complete silt. Its percentage in the fraction of the silt that reaches the ld is calculated :— $\frac{\text{Per cent calcium carbonate (column 4) x 100}}{\text{Per cent calcium carbonate (column 4) + per cent fine silt (column 9) + per cent clay (column 10)}}$

ttle change in the soils of the Ravi, Chenab nd Jhelum areas. Deterioration of physical onditions may take place on the Sutlej and ndus but no material change would be expected n the areas served by the remaining rivers. The conclusions regarding the Indus may be of onsiderable importance in the development of he Thal area. This area is situated between the ndus and Jhelum-Chenab rivers and is soon to be rigated from the Indus by means of canals aking off at Kalabagh. The soils of the Thal onsist of an unknown depth of loess resting on lluvium. This loess is easily erodable which may ad to high maintenance costs of the channels. t is very permeable, which means a low duty for he water and possibly a rapid rise in the water- able. The high content of the finer fractions in he Indus silt may lead to the formation of non- odable berms in the canals as it will impart cohesion to the loess. It will also tend to increase the water retaining power of the soils and should result in time in an increase in the duty of the water.

(b) *Calcium carbonate content of silts*

It will be noticed that the calcium carbonate content of silts varies considerably from river to river. The highest quantities are present in the river Sutlej silts. A comparison of the figures for the pre-monsoon and monsoon periods clearly shows that the calcium carbonate is derived from the area in the snow-covered higher hills since the percentage falls with the addition of silt derived from the lower hills during the monsoon.

The silts of the Jhelum and Indus also have a high content of calcium carbonate. There is little difference in the percentages for the pre-monsoon and monsoon periods. This is probably

TABLE III

Analytical results of silt samples collected during 1935-36

Name of river	Name of site	Time of taking silt sample with reference to the rainy period	Analysis of the HCl extract		Results expressed in mgm. per 100 gm. of silts.			Exchangeable base content (Results expressed in mill-equivalents)			
			Per cent K_2O	Per cent Na_2O	Total P_2O_5 (in HCl extract)	Available P_2O_5	Nitrogen	Ca	Mg	K	Na
1	2	3	4	5	6	7	8	9	10	11	12
Sutlej	Ruper	Before	0·70	0·09	95·73	1·20	6·00	28·50	1·60	0·38	0·22
		During	0·61	0·08	109·10	1·28	8·40	17·40	2·30	0·37	0·52
		After	0·60	0·12	118·55	...	12·0	11·40	1·40	0·29	0·41
Beas	Mandi (plain)	Before	0·63	0·06	89·5	...	...	8·70	0·65	0·55	0·15
		During	0·64	0·05	157·00	...	...	10·10	0·60	0·55	0·10
		After	0·51	0·05	181·85	...	...	8·70	0·63	0·39	0·21
Ravi	Madhopur	Before	0·57	0·10	134·00	0·93	6·0	3·90	2·10	0·44	0·36
		During	0·38	0·04	152·50	1·10	8·40	5·80	1·70	0·00	...
		After	0·60	0·06	94·55	0·90	8·40	4·20	1·10	0·14	0·26
Chenab	Marala	Before	0·55	0·08	130·9	0·95	9·80	6·90	1·60	0·32	0·68
		During	0·52	0·06	109·1	1·18	12·60	16·90	2·10	0·33	0·37
		After	0·46	0·10	105·9	...	6·30	5·10	1·10	0·18	0·62
Jhelum	Rasul	Before	0·55	0·13	140·10	1·50	14·0	14·70	2·80	0·76	0·04
		During	0·98	0·12	146·10	1·88	24·50	17·70	1·50	0·99	0·11
		After	0·58	0·13	140·70	...	...	14·10	1·80	0·80	0·30
Indus	Ghazighat	Before	1·11	0·20	151·80	0·50	11·20	16·20	2·70	0·48	0·32
		During	0·84	0·18	117·40	0·93	12·60	20·30	2·10	0·53	0·27
		After	1·33	0·18	95·70	0·75	21·00	19·20	2·20	0·52	0·18

TABLE IV

*Analytical results of silt samples collected during the year 1936-37**

Name of river	Name of site	Time of taking silt sample with reference to the rainy period	Per cent $CaCO_3$ content	*p*H	Mechanical analysis (Results expressed on air-dry basis)					clay as per cent fraction of the total 0·01 mm. particles in the silt sample	Per cent Ca Co_3 content in the portion of silt reaching the field
					Sand >0·20	Fine sand 0·2 to 0·02	Silt particles between 0·02 & 0·01	Fine silt particles between 0·01 & 0·002	Clay 0·00 2* mm.		
1	2	3	4	5	6	7	8	9	10	11	12
Sutlej	Rupar	Before	10·00	7·68	1·44	42·01	14·18	22·93	7·00	23·38	25·04
		During	5·50	8·24	2·78	43·20	12·50	22·59	9·40	29·05	14·83
		After	5·25	8·20	3·19	10·61	6·78	40·45	31·60	43·86	6·79
Ravi	Madhopur	Before	0·75	7·70	20·29	40·56	14·25	17·90	2·70	13·11	3·51
		During	0·50	7·87	4·19	49·14	20·16	18·98	2·98	13·57	2·23
		After	1·00	8·40	37·94	29·37	13·35	11·45	3·45	23·16	6·29
Chenab	Marala	Before	3·25	7·90	10·36	52·03	17·40	18·00	2·90	13·88	13·46
		During	3·00	8·18	0·73	67·19	14·23	9·05	3·05	25·21	19·87
		After	2·50	7·80	0·96	18·71	14·73	39·10	19·40	33·16	4·09
Jhelum	Rasul	Before	8·75	8·20	1·36	79·84	7·55	2·90	0·45	13·43	72·32
		During	7·75	8·28	0·70	36·69	13·80	27·50	8·15	22·89	17·86
		After	10·86	8·14	1·89	27·39	25·45	25·45	7·05	21·69	25·05

*For explanation of the various columns see bottom of Table II

TABLE V

Analytical results of silt samples collected during 1936-37

ame of river	Name of site	Time of taking silt sample with reference to the rainy period	Analysis of the HCl extract Results expressed in mg. per 100 gm. of silts					Exchangeable base content (Results expressed in milli-eqaivalents)			
			Per cent K_2O	Per cent Na_2O	Total P_2O_5 (in HCl extract)	Avail-able P_2O_5	Nitro-gen	Ca	Mg	K	Na
ej . .	Rupar . .	Before .	0·80	0·11	128·86	3·66	46·20	14·70	1·40	0·35	0·10
		During .	0·91	0·10	163·28	3·82	21·70	9·30	1·40	0·47	0·06
		After . .	1·50	0·07	100·0	2·63	47·32	14·80	2·28	0·83	0·07
i . ,	Madhopur . .	Before .	0·31	0·08	140·96	1·83	30·80	3·00	1·20	0·24	0·16
		During .	0·70	0·02	174·80	1·98	43·12	5·40	1·05	0·28	0·37
		After . .	0·76	0·05	110·00	1·53	53·62	4·00	0·58	0·36	0·04
jab . .	Marala . .	Before .	0·71	0·08	180·54	3·28	40·32	5·40	0·09	0·09	0·21
		During .	0·43	0·05	169·00	2·64	17·98	7·80	1·30	0·38	0·10
		After . .	1·37	0·05	100·0	1·83	54·32	17·40	2·25	0·39	0·11
um . .	Rasul . .	Before .	0·42	0·11	146·08	0·64	26·60	7·40	0·80	0·25	...
		During .	0·69	0·47	189·50	2·84	30·80	15·20	1·55	0·41	0·07
		After . .	1·25	0·12	160·00	1·87	62·08	13·80	1·18	0·56	0·04

e to the fact that the monsoon does not affect catchment areas of these rivers to the same ent as those of the other rivers of the Punjab. Next in importance with reference to calcium bonate content is the silt of the Chenab river. e quantities of calcium carbonate reaching the ds (it is presumed that all the calcium carbonate ntent is very finely divided and is carried to the ds along with the clay and fine silts fractions suspensions vide column 12, Tables II & IV) he areas served by the canals taking off from the enab, however, will be relatively small. Both Beas and the Ravi rivers have a very low cium carbonate content.

The zamindars in the Punjab regard the Ravi as having the greatest fertilizing value. It is ious that this silt contains the lowest percent- e of calcium carbonate and therefore this nion appears to conflict with the views general- held on the value of calcium carbonate. A ssible explanation is that it has not re fertilizing value but that it causes s deterioration of the soil. The soils of the njab plains generally contain sodium salts, the ef of which is sodium sulphate. As the result the presence of these salts the soil becomes aline under irrigation and in the final stages deterioration contains sodium carbonate. It l been shown experimentally [Puri, Taylor and ghar, 1937] that calcium carbonate reacts with alkaline sodium clay of the Punjab soils d sodium carbonate is rapidly formed. A silt gh in calcium carbonate may therefore lead to the deterioration of soils similar to those in the Punjab while a silt low in calcium carbonate will have no harmful effect. On this basis some respect must be paid to the opinions held by the local zamindars. It is curious that support is lent to the above by the large areas of alkaline lands which occur in the Sutlej, Jhelum and Indus valleys and their absence in the areas served by the Upper Bari Doab Canal which takes off from the Ravi.

(c) The chemical analysis of the silts show very small quantities of nitrogen, phosphates and potash. It is doubtful whether after their transport with water for considerable distances any of these constituents would be available for the plant until they have been subjected to weathering after deposition.

No field experiments have been carried out to determine the fertilizing value of the silts. It is, however, a world-wide belief that silts have a definite fertilizing value. Analysis of silts in various parts of the world do not support this. It seems probable that the origin of the ideas regarding the fertilizing properties of the silt is bound up with water supply. In all countries where irrigation is practised water is the principal factor limiting crop yields. If a large deposit of silt is obtained it means that a big depth of water has been present and therefore that the reserve supplies of water in the soil after the deposition of the silt are greater in areas of high silt deposits than in areas of low silt deposit. This is the case in the basin irrigation practised in Upper Egypt. No

attempt seems to have been made to separate the effects of the silt and water factors.

SUMMARY

The chemical analysis of silts carried in suspension by the various rivers of the Punjab has been discussed in order to throw some light on their fertilizing properties.

It is shown that the silts contain very small quantities of nitrogen, phosphates, and potassium and cannot thus be regarded as direct fertilizers.

Differences between the silts of the various rivers have been brought out from a consideration of firstly the percentage fractions of the silts that are likely to reach the fields and secondly their calcium carbonate contents. It is shown that from the physical point of view the plains irrigated from the Sutlej and Indus would tend to become heavier as regards soil type and there would be little change in the soils of the Ravi, Chenab and Jhelum areas. Deterioration of physical conditions may take place on the Sutlej and Indus but no material change would be expected on the areas served by the remaining rivers.

Silts high in calcium carbonate may lead to deterioration of soils while those low in calcium carbonate will have no harmful effects.

ACKNOWLEDGEMENT

We take this opportunity to thank Dr E McKenzie Taylor, C.I.E., M.B. E., Ph.D., D.Sc. Director, Irrigation Research, Punjab, for his very valuable suggestions in connection with this study

REFERENCES

Bal, D. V. (1925). The determination of nitrogen in heavy clay soils. *J. agric. Sci.* **14**, 454

Hoon, R. C. and Taylor, E. M. (1931). An examinatio of the factors determining the hydrogen ion concentra tion of suspension of Punjab soils. *Mem. Punjab Irr Res. Inst.* Vol. **4**, No. 1 and 2

Puri, A. N. (1931). A new method of estimating tota carbonates in soils. *Imp. Inst. Agri. Res. Pusa (India Bull. No.* 206

———————and Asghar, A. G. (1936). Estimation available phosphates in the soil by CO_2 extractio *Soil Sci.* **42**, 39

———————Taylor, E. M. and Asghar, A. G. (1937). S deterioration in the canal irrigated areas of the Punjal III. *Punjab Irri. Res. Pub.* Vol. **4**, No. 9

STUDIES ON BASE EXCHANGE

I. COMPARISON OF BASE EXCHANGE CAPACITIES AND DEGREE OF SATURATION SOME INDIAN SOILS OBTAINED BY DIFFERENT METHODS*

By S. K. MUKHERJEE,** M. Sc., and S. K. NANDI,§ M. Sc., Colloid Research Laboratory, Universit College of Science and Technology, Calcutta

(Received for publication on 7 May 1943)

IN assessing the fertility and other properties of a soil, its base exchange capacity (b. e. c.) and content and nature of exchangeable bases are of importance. The methods in vogue, however, give different estimates of the same quantity and this lack of uniformity becomes more prominent when the exchangeable cation is partly or wholly hydrogen. The need of one method for each tpye of measurement which can be used for a wide variety of soils is obvious and has been emphasized by many [Russell, 1938]. Although this ideal ma be difficult of accomplishment in view of diff ences in soils, an agreement as to which method most suitable for a particular group of Indian so is most desirable.

2. A comparative study has been made of t following methods :

Base exchange capacity (*T*)

(1) Parker's barium acetate-ammonium chlor method [Parker, 1929].

In addition to the estimation of Ba++ adsor from a neutral normal barium acetate soluti estimation was made of the NH_4^+ adsorbed fr normal NH_4Cl solution used to displace the sorbed Ba++.

(2) Schollenberger and Dreibelbis' met [1930].

NH_4^+ adsorbed from a neutral normal amm nium acetate solution was estimated.

* The results given in this paper were published in the Annual Report for 1938-39, 1939-40 and 1940-41 on the working of the scheme of research into the properties of colloid soil constituents financed by the Imperial Council of Agricultural Research and directed by Prof. J. N. Mukherjee

** Assistant Soil Chemist under the above scheme during 1938-39

§ Assistant Soil Chemist under the above scheme since 1939

Total exchangeable bases (S)

(3) R. Williams' method [1929].

S was also obtained by summing up the individual exchangeable bases separately estimated.

Individual exchangeable bases

(4) Hissink's method [1923].

(5) Hissink-Tiulin method [Tiulin, 1927].

These two methods were employed for estimating exchangeable Ca and Mg. Exchangeable Na K and also Mg and Ca of non-calcareous soils were estimated in the ammonium-acetate extract of method (2).

Exchangeable hydrogen

(6) Hardy and Lewis' method [1929].

(7) Titration with baryta in presence of N-$BaCl_2$. The amount of baryta required to attain *p*H 7·0 was estimated from the titration curve.

3. The soils which have been used for this comparison are enumerated in Table I.

4. The data are summarized in Table II.

Base exchange capacity. Methods 1 and 2 show good agreement both in the case of soils (Table II) and clays (Table III) although different cation effects are involved. The reaction between a salt and the soil absorption complex depends, besides other factors, on the *p*H of the equilibrium solution and the cation effects [Mitra, 1936; Mukherjee, Mitra and Mukherjee, 1937; Mitra, 1940; Mitra, Mukherjee and Bagchi, 1940; Mukherjee and Mitra, 1942]. At the high concentration (normal) of the salts used in methods 1 and 2, the high *p*H of the solution and the high degree of buffering offered by the acetates, the differences in the nature of the cation (i.e. the cation effect) becomes negligible. These different factors have been considered in greater detail in Part II of the paper.

TABLE I

Lab. No.	*Description*	*Calcium carbonate* (per cent)	*pH*
23	Ganges silt (Rajshahi Farm, Bengal)	3·8	6·2
46	Padegaon 'B' type, non-lateritic (0-12 in.), Nira, Poona	5·7	8·6
47	Padegaon 'D' type, non-lateritic (0-12 in.), Nira, Poona	6·1	8·5
53	Highland acid soil (0-6 in.) Latekujan experimental station, Assam	nil	5·3
55	Highland acid soil (0-6 in.), Oating, Assam	nil	5·0
10	Suri Farm soil, Bengal (0-6 in.)	nil	5·7
14	Burdwan Farm soil, Bengal (0-6 in.)	nil	5·8
20	Kalyanpur Farm soil, Cawnpur (0-6 in.)	0·54	7·3
25A	Black cotton soil from Satara, Bombay (0-6 in.)	2·6	8·5

TABLE II

Lab. No.	Soil	Base exchange capacity (T)			Total exchangeable bases		V = 100X S/T	*p*H (glass electrode)	Carbonate content (m.e.)	Exchangeable hydrogen		
		Schollenberger's method	Parker's		R. Williams' method	S = Ca + Mg + K + Na				Hardy and Lewis method	Titration with $Ba(OH)_2$ in presence of N-$BaCl_2$	T—S (calculated)
			Ba^{++} adsorbed	NH_4 + adsorbed								
10	Suri	5·6	5·8	5·3	n. d.	5·0**	89·0	5·7	nil	0·3	0·6	0·6
14	Burdwan	6·3	6·5	6·9	4·3	4·1**	63·8	5·8	nil	0·2	0·8	2·4
16	Krishnagar	14·1	13·2	13·8	7·4	6·9	53·4	5·1	nil	1·8	2·2	6·2
20	Kalyanpur	11·9	11·6	11·8	13·9	13·7**	100·0	7·3	18·0	..	..	..
23	Rajshahi Ganges silt	14·6	15·3	15·1	..	14·5	96·7	8·7	126·7	..	..	..
25	Black cotton (Satara)	60·4	58·9	54·4	57·7	54·8**	96·0	8·3	86·3	..	..	..
46	Padegaon soil 'B' type	49·5	51·4	n. d.	..	47·0*	93·1	8·2	190·0	..	..	..
47	Padegaon soil 'D' type	64·4	65·3	64·7	..	63·8*	98·3	8·1	204·3	..	..	..
53	Acid soil (Latekujan)	8·1	8·3	8·0	3·6	3·7	45·0	5·4	nil	4·0	3·9	4·5
55	Acid soil (Oating)	7·5	8·0	8·1	2·6	2·6	33·0	5·3	nil	3·9	4·8	5·3

* Excluding K

** Excluding Na

Total exchangeable bases. The total content of exchangeable bases (S) estimated by method 3 is in agreement with the sum of the individual exchangeable bases separately determined in the case of the two acid soils only. With the other three soils containing high percentages of $CaCO_3$, the S values determined by the method 3 were not satisfactorily reproducible. Similar observations have been made by R. Williams himself [1929] with highly calcareous soils.

Degree of saturation. V ($= \frac{S}{T} \times 100$) values calculated from the average T and S show that soil Nos. 20, 23, 25, 46 and 47 are almost base saturated, the major constituent of the exchangeable bases being calcium. The calcium saturation has been brought about by the free $CaCO_3$ present in these soils. The soil reaction is alkaline. The degree of saturation of the rest of the soils varies from 33 to 64 per cent. These latter soils do not contain free $CaCO_3$ and have acidic reaction.

pH values. The *p*H values of the aqueous suspension of the soils determined by the glass electrode are given in Table II. The *p*H of the base saturated soils varies from 7·3 to 8·3 and that of acid soils from 5·1 to 5·8.

TABLE III

Base binding capacities of H-clays by different methods

Lab. No.	H-clays prepared from soils	Base binding capacity of clay		
		Paker's		Schollenberger
		NH_4 + adsorbed	Ba++ adsorbed	
10	Suri . . .	37·0*	37·0*	..
20	Kalyanpur . .	..	54·6*	..
23	Rajshahi Ganges silt	48·1	53·0	50·4
46	Padegaon soil 'B' type	..	89·8	86·0
47	Padegaon soil 'D' type	..	102·7	97·0
53	Latekujan soil .	42·0	40·6	40·5
55	Oating soil . .	28·0	28·5	26·5

* Organic matter was removed from them by treatment with H_2O_2

Exchangeable hydrogen. Any excess of T over S means that the soil absorbing complex has replaceable cations other than those determined, viz. Ca, Mg, K and Na. The difference between T and S is usually bridged over by assuming the presence of hydrogen alone in an exchangeable form. Exchangeable hydrogen directly determined by methods 6 and 7 shows that the observed values are lower than those calculated as T-S (Table II). The lower value indicates that all the exchangeable hydrogen ions are not probably brought into a state of neutralization reactivity under the conditions of experiment. The higher value of exchangeable hydrogen obtained by method 7 is due to the higher concentration of the Ba++ ion and its stronger adsorbability§. In the case of the other five soils the *p*H on the addition of either $BaCl_2$ or $CaCl_2$, although it diminishes, remains above 7·0.

5. The values for exchangeable Ca and Mg in non-calcareous soils (Table IV) determined by methods 4, 5 and 2 agree very closely. Exchangeable K and Na estimated by method 2 are present in minute quantities.

6. Of the exchangeable bases, calcium constitutes about 70 to 90 per cent of the base exchange capacity of the base saturated soils. It is about 20 to 50 per cent in the case of the acid soils. Magnesium constitutes about 5 to 30 per cent of the b. e. c. of the different types of soils used. Potassium and sodium contents are 0·5 to 9 per cent and 0·8 to 5 per cent, respectively. Exchangeable hydrogen constitutes about 10 to 50 per cent of the b. e. c. of the acid soils.

7. *Comparison of soils.* The Padegaon 'B' and 'D' types and black cotton soils have the highest T-value (50 to 65 m. e.) corresponding to their high clay contents. They are also base saturated containing free $CaCO_3$ and the contents of both exchangeable Ca and Mg are high. Soil Nos. 20 and 23 have comparatively low T-value and are almost completely saturated with Ca alone. The rest are acid soils which (excepting soil No. 16) have very low T-value.

SUMMARY AND CONCLUSIONS

A comparative study has been made of some outline methods of determining the base exchange capacity, exchangeable bases, etc. of Indian soils as also of hydrogen clays isolated from them. Several types of soils have been selected for this work and the results on ten soils and seven hydrogen clays have been recorded in this paper.

The values of base exchange capacities (T) of soils and clays given by Schollenberger's and Parker's methods are in good agreement with each other. Rice Williams' method of determining S-value is not suitable for soils which contain fairly large quantities of $CaCO_3$. For non-calcareous soils, the contents of exchangeable Ca and Mg obtained by both Schollenberger's and Hissink-Tiulin mehods are in fair agreement. In the case

§ The estimation of the exchangeable hydrogen of the soil and the factors determining it have been discussed in detail in Part II

TABLE IV

Individual exchangeable bases in m. e. per 100 gm. of soil

Lab. No.	Soil	Ca	Mg	K	Na
10	Suri	2·8 Hissink-Tiulin 2·8 Schollenberger	1·9 Schollenberger	0·3	n. d.
14	Burdwan	3·2 Hissink-Tiulin 3·3 Schollenberger	0·6 Schollenberger	0·3	n. d.
16	Krishnagar	5·6 Hissink-Tiulin 5·3 Schollenberger	0·6 Schollenberger	0·5	0·2
20	Kalyanpur	10·2 Hissink-Tiulin 10·0 Hissink	2·7 Schollenberger	0·8	n. d.
23	Rajshahi Ganges silt	11·7 Hissink 11·2 Hissink	2·1 Hissink	0·4	0·5
25	Black cotton (Satara)	40·2 Hissink-Tiulin	14·3 Hissink-Tiulin	0·3	n. d.
46	Padegaon 'B' type	36·8 Hissink-Tiulin	9·8 Hissink-Tiulin	n. d.	0·4
47	Padegaon 'D' type	47·9 Hissink-Tiulin 48·1 Hissink	14·9 Hissink-Tiulin	0·9	n. d.
53	Acid soil (Latekujan)	2·0 Hissink-Tiulin 2·0 Schollenberger	0·7 Hissink-Tiulin 0·7 Schollenberger	0·6	0·4
55	Acid soil (Oating)	1·7 Hissink-Tiulin 1·6 Schollenberger	Trace Hissink-Tiulin Trace Schollenberger	0·7	0·2

of calcareous soils, the exchangeable Ca and Mg have to be determined by the Hissink or Hissink-Tiulin methods. Exchangeable hydrogen of acid soils determined by either Hardy and Lewis' method or by titration with baryta in presence of N-$BaCl_2$ is much less than the difference T—S. The degree of saturation of the soils V ($= \frac{S}{T} \times 100$) calculated from the average values of S and T range from about 33 to 64 per cent in the case of soils which do not contain free $CaCO_3$ and have acidic reaction, to about 100 per cent in the case of soils containing free $CaCO_3$. Of the exchangeable bases calcium constitutes about 70 to 90 per cent of the b. e. c. of the base saturated soils and about 20 to 50 per cent in the case of acidic soils. Exchangeable K and Na are present in very small quantities and the content of Mg is only appreciable (about 30 per cent) in the case of black cotton type of soils. Exchangeable hydrogen consitutes about 10 to 50 per cent of the b. e. c. of the acid soils.

REFERENCES

Hissink, D. J. (1923). Method for estimating absorbed bases in soils. *Soil Sci.* **15**, 269

Mitra, R. P. (1936). On the nature of reactions responsible for soil acidity, V. Titration curves of clay acids. *Indian J. agric. Sci.* **6**, 555

Mitra, R. P. (1940). On the nature of reactions responsible for soil acidity, VII. The electro-chemical properties of colloidal solutions of hydrogen clays. *Indian J. agric. Sci.* **10**, 317

——— Mukherjee, S. K. and Bagchi, S. N. (1940). On the nature of reactions responsible for soil acidity, VI. The variability of total neutralisable acid of colloidal solutions of hydrogen clays. *Indian J. agric. Sci.* **10**, 303

Mukherjee, J. N., Mitra, R. P. and Mukherjee, S. (1937). The characteristic properties of colloidal solutions of acidic substances which distinguish them from acids in true solution. *Trans. Natl. Inst. Sci. India*, **1**, No. 10, 227

——— (1942). On the nature of reactions responsible for soil acidity, IX. The acid character of hydrogen clay. *Indian J. agric. Sci.* **12** 433

Parker, F. W. (1929). The determination of exchangeable hydrogen in soils. *J. Amer. Soc. Agron.* **21**, 1030

Russell, E. J. (1938). Report on the working of schemes, under the Imperial Council of Agricultural Research, India

Schollenberger, C. J. and Dreibelbis, F. R. (1930). Analytical methods in base exchange investigation in soils. *Soil Sci.* **30**, 161

Tiulin, I. V. (1927). On the method of determining exchangeable calcium and magnesium in soils containing alkaline-earth carbonates. *Pedology* **1**, 5

Williams, R. (1929). The determination of exchangeable bases in soils. *J. agric. Sci.* **19**, 589

A STATISTICAL STUDY OF FLOWER PRODUCTION IN COTTON

By D. N. Nanda and Mohammad Afzal, Cotton Research Laboratory, Lyallpur, and V. G. Panse, Institute of Plant Industry, Indore

(Received for publication on 16 July 1943)

(With four text-figures)

In the first paper of this series [Afzal and Iyer, 1934] the growth in height of the main axis of the cotton plant was studied statistically and it was shown that Blackman's [1919] law of compound interest held good so far as rate of growth in height of the cotton plant at Lyallpur was concerned. It was also emphasized that Maskell's [1930] idea of presenting the developmental data of cotton in a simple and easily comparable form should be followed up by research workers in different parts of the world so that 'it may be more easily possible to compare the curves from one place with the curves from another place, and relate the changes to changing intensity of environmental factors'. With this idea in view the daily rate of growth in height was studied and it was found that the equation $H = Ae^{bt}$ could be fitted to the experimental curves. This study has now been carried a step further and an attempt has been made to find out a mathematical expression for the flowering curves of cotton. Although the value of flowering records to the plant breeder and the agronomist has been criticized by one of us [Afzal, 1941], these records are useful to the plant physiologist who is trying to disentangle the various growth phases of the cotton plant and to study the effect of environment on these growth phases.

It must be emphasized here that the rate of flowering is, perhaps, more important to the plant physiologist than the rate of growth in height as flowering immediately precedes boll formation. Prescott [1922] was the first to study statistically the flowering of cotton in Egypt. He used equation (*ii*) for this purpose.

$$(i)\ \text{Log}_e \frac{ax}{a-x} = kat$$

$$(ii)\ \text{Log} \frac{x}{a-x} = K(t-t_1)$$

$$(iii)\ \frac{dx}{dt} = kx(a-x)$$

where a is the total number of flowers produced, x is the number of flowers produced up to time t, and K and k are two constants, where $K = ak$ Loge $= 0{\cdot}4343\ ak$, and t_1 is the time when $x = a/2$. We have employed equation (*ii*) and it has been shown that the values of K are higher in Lyallpur than in Egypt. This may be due either to the varieties under experiment or the environmental conditions obtaining during the years of experiment at the two places.

Bartel and Martin [1938] have also employed the same equation in fitting curves to the dry weight per stalk and the grain weight per head of two varieties of grain sorghum, Dwarf Hegari and Double Dwarf Yellow Milo, under normal and late planting. They have also investigated the effect of seed size on the rate of growth of two varieties of corn, four of sorghum and one of proso and in every case the same logistic equation was found to fit the curves. It thus appears that the compound interest law has a very wide application in plant physiology studies.

Material

Three varieties of Punjab-American cotton (*G. hirsutum* L.) namely, 4F, 289F and 289F/43 and one variety of Punjab *desi* cotton (*G. arboreum* var. *indica Forma bengalensis*, H. & G.) 39 Mollisoni, were used for this purpose. It will not be out of place here to mention a few salient features of these strains.

4F. This is the oldest commercial variety of Punjab-American cottons. It was released by the Punjab Department of Agriculture for general cultivation in 1914 and has since then been one of the most popular varieties. This cotton is medium in maturity, giving its first picking in the 4th week of October. The fibre is 7/8 in. and is capable of spinning on the average 24 highest standard warp counts. Flowering records are available for seven years.

289F. This variety was grown on a commercial scale for the first time in 1921 in the Lower Bari Doab Canal Colony and was very popular in some parts of it. The area under this cotton is now decreasing. This variety is later than 4F, giving its first picking in the second week of November. Its fibre length is $1\frac{1}{32}$ in. and has been adjudged as capable of spinning 44 highest standard warp counts. Flowering records are available for seven years.

289F/43. This is a very early maturing variety and was released for general cultivation in 1934. Due to its early maturing habit and drought resistance it has found great favour in the parts of Lower Bari Doab Canal Colony and south western

stricts of the Punjab. Its fibre length is $1\frac{1}{32}$ in. nd has been adjudged as capable of spinning 40 ghest standard warp counts. Flowering records re available for three years.

39 Mollisoni. This is the most popular variety f Punjab *desi* cottons in the Central Canal Colony istricts of the Punjab and occupies about 39 per ent of the total area under *desi* cotton in the rovince. The fibre length of this variety is /8 in. and is capable of spinning 9 highest stand-rd warp counts. Flowering records of this cotton re available for five years.

The procedure for recording the daily production f flowers was the same as employed in Egypt. Before the commencement of flowering 200 A. P. verage plants, meaning plants of average size nd normally spaced) were selected at random nd the actual number of flowers which opened on hese plants every day was recorded on special ards prepared for the purpose. The casualties uring the course of the season were carefully oted and the average number of flowers produced er plant per day (P. P. p. d.) were worked out. hese data along with the summation data were sed in the statistical analysis.

One peculiarity of the Punjab-American cottons ay here be noted.. All flowers produced on these arieties up to or about the middle of August re shed due to the non-dehiscence of anthers Trought, 1928]. Thus the 'effective' flowering n these varieties starts from the beginning of September. No non-dehiscence of anthers occurs in 39 Mollisoni and other indigenous cottons.

Method

(*a*) *Summation curves.* The flowering season was divided up into intervals of five days and the total number of flowers produced per plant up to each interval was plotted. The summation curves of all the varieties were of the characteristic S-shape. In order to see the goodness of fit of the calculated with the observed summation curves, the logistic equation $\text{Log } \frac{x}{a-x} = K\ (t-t_1)$ was transformed as $Y = A + Bt$ where $Y = \log \frac{x}{a-x}$, $A = -Kt_1$, $B = K$.

As all the summation curves were asymmetrical it was necessary to fit an equation of the general nature, such as $Y = A + Bt + Ct^2 + Dt^3$.

Since the independent variable occurred at equal intervals, the regression curves of the third degree were fitted to each variety for the different years by the method of orthogonal polynomials given by Fisher [1936]. The origin was taken on the date of first flowering, but in the actual calculations, the first observation was neglected as the number of flowers on the date of origin was extremely small.

The third degree curves were fitted to the data and the analysis of the sum of squares contributed by the linear, the quadratic and the cubic regressions was worked out and is given in Table I.

Table I

Analysis of sum of squares

1	2	3	4	5	6	7	8	9	10
Year	Total d.f.	Total S. S.	Linear component	Q. component	Cubic component	Residual	Per cent L. C. Total	Per cent Q. C. Total	Per cent C. C. Total
89F.									
1926-27 . .	15	45·1771	44·1461**	0·8110**	0·0299	0·1901	97·72	1·80	0·07
1927-28 . .	21	65·9184	59·3262**	5·6471**	0·1524	0·7927	90·00	8·57	0·23
1928-29 . .	22	60·7235	57·7149**	1·3204**	0·6126**	1·0756	95·05	2·17	1·01
1929-30 . .	13	35·9565	35·3784**	0·0002	0·1745	0·4034	98·39	0·001	0·49
1930-31 . .	20	69·2945	56·4386**	11·4319**	0·2860	1·1380	81·45	16·50	0·41
1931-32 . .	19	40·6052	34·6213**	5·4794**	0·3061**	0·1984	85·26	13·49	0·75
1932-33 . .	11	31·4646	29·9939**	0·5521**	0·7793**	0·1393	95·33	1·75	2·48

TABLE I—*contd.*

1	2	3	4	5	6	7	8	9	10
Year	Total d.f.	Total S. S.	Linear component	Q. component	Cubic component	Residual	Per cent L. C. Total	Per cent Q. C. Total	Per cent C. C. Total
4F.									
1926-27 . .	24	118·5894	115·4529**	0·0002	0·3579	2·7784	97·36	0·0002	0·30
1927-28 . .	23	65·6088	55·4122**	5·1611**	4·5657**	0·4698	84·46	7·87	6·96
1928-29 . .	22	63·2408	60·7436**	2·1158**	0·0088	0·3726	96·05	3·35	0·014
1929-30 . .	14	46·1944	44·6832**	0·0314	0·4129	1·0669	96·73	0·07	0·89
1930-31 . .	18	43·3527	32·2392**	9·1691**	1·8826**	0·0618	74·36	21·15	4·34
1931-32 . .	20	37·3880	36·1486**	0·5053**	0·4413**	0·2928	96·69	1·35	1·18
1932-33 . .	10	33·8449	33·3990**	0·1132	0·2517**	0·0810	98·68	0·33	0·74
289F/43.									
1930-31 . .	17	47·8601	45·1559**	2·1244**	0·3711**	0·2087	94·35	4·44	0·78
1931-32 . .	21	40·0819	35·1498**	2·3367**	2·1723**	0·4231	87·69	5·83	5·42
1932-33 . .	16	64·6079	64·0812**	0·2286**	0·0619	0·2362	99·18	0·35	0·09
Mollisoni.									
1928-29† . .	11	16·4141	15·8559**	0·4956**	0·0426**	0·0200	96·60	3·02	0·26
1929-30 . .	12	40·2026	39·5666**	0·1674**	0·4620**	0·0066	98·42	0·42	1·1
1930-31 . .	16	48·8633	48·1078**	0·6353**	0·0191	0·1011	98·45	1·30	0·03
1931-32† . .	9	12·9864	12·8324**	0·1368**	0·0127**	0·0045	98·81	1·05	0·09
1932-33 . .	14	48·7757	48·2423**	0·0009	0·0060	0·5265	98·91	0·002	0·01

† During these two years there were two flushes of flowers but only the first which was the main flush has b considered. But by leaving out the 2nd flush a further asymmetery was introduced in the summation curves.

It will be seen from Table I that the percentage of sum of squares contributed by the linear regression was overwhelmingly large and that the mean variance due to the linear regression was always highly significant, whereas that for quadratic and cubic was also significant in a large number of cases. This was because of the asymmetrical nature of the actual summation curves in comparison to the symmetrical curves obtained by the equation $\text{Log } \frac{x}{a-x} = K\ (t-t_1)$.

Since the method of orthogonal polynomials has the advantage of reducing the equation from any higher degree to the lower ones, the constants of the cubic, quadratic, as well as those of the linear ones could be easily obtained for all the varieties in the different years. The average polynomial curves for each variety were found to be significant up to the third degree and for t sake of brevity only the cubic equations are giv in Table II.

The values of Y as calculated from the line quadratic and the cubic equations (Table II) well as the observed values were plotted agai the time interval and by way of illustration graphs for 1930 are given in Fig. 1. It will seen from Fig. 1 that the cubic equation gave best fit in the case of all the three Americ varieties, while both the quadratic and the cu equations gave a better fit than the linear equat in the case of Mollisoni. The trend was simila other years also, which will be dealt with in de later on.

After having calculated Y, the number of flow x at any time t was calculated by the transfo ation needed in the equation $Y = \log \frac{x}{a-x}$.

TABLE II

Cubic equations

289F	(*i*)	1926-27	Y	=	—2·223,965	+	0·260,338t	—	0·002,721t^2	+	0·000,574t^3
	(*ii*)	1927-28	Y	=	—3·036,772	+	0·070,324t	—	0·000,361t^2	+	0·000,420t^3
	(*iii*)	1928-29	Y	=	—2·739,243	—	0·151,149t	+	0·031,447t^2	—	0·000,714t^3
	(*iv*)	1929-30	Y	=	—3·960,136	+	0·702,187t	—	0·049,969t^2	+	0·002,233t^3
	(*v*)	1930-31	Y	=	—2·538,557	—	0·024,527t	+	0·000,214t^2	+	0·000,678t^3
	(*vi*)	1931-32	Y	=	—2·373,837	+	0·082,995t	—	0·008,573t^2	+	0·000,833t^3
	(*vii*)	1932-33	Y	=	—4·381,010	+	1·587,700t	—	0·180,278t^2	+	0·008,202t^3
4F	(*i*)	1926-27	Y	=	—4·157,060	+	0·130,067t	+	0·015,923t^2	—	0·000,410t^3
	(*ii*)	1927-28	Y	=	—3·441,440	+	0·595,048t	—	0·052,526t^2	+	0·001,690t^3
	(*iii*)	1928-29	Y	=	—2·344,066	+	0·089,859t	+	0·004,633t^2	+	0·000,086t^3
	(*iv*)	1929-30	Y	=	—3·875,283	+	0·781,191t	—	0·061,682t^2	+	0·002,685t^3
	(*v*)	1930-31	Y	=	—2·274,375	+	0·327,454t	—	0·048,282t^2	+	0·002,476t
	(*vi*)	1931-32	Y	=	—2·859,312	+	0·362,501t	—	0·023,040t^2	+	0·000,842t^3
	(*vii*)	1932-33	Y	=	—3·793,054	+	1·264,579t	—	0·126,378t^2	+	0·006,383t^3
289F/43	(*i*)	1930-31	Y	=	—2·723,779	+	0·329,255t	—	0·023,625t^2	+	0·001,332t
	(*ii*)	1931-32	Y	=	—2·526,275	+	0·504,729t	—	0·045,603t^2	+	0·001,585t^3
	(*iii*)	1932-33	Y	=	—4·355,070	+	0·627,268t	—	0·023,413t^2	+	0·000,666t^3
Mollisoni	(*i*)	1928-29	Y	=	—2·952,286	+	0·785,741t	—	0·056,652t^2	+	0·001,917t^3
	(*ii*)	1929-30	Y	=	—3·278,704	+	0·916,158t	—	0·090,333t^2	+	0·004,737t^3
	(*iii*)	1930-31	Y	=	—2·544,269	+	0·254,428t	—	0·000,937t^2	+	0·000,370t^3
	(*iv*)	1931-32	Y	=	—2·907,296	+	0·725,994t	—	0·049,607t^2	+	0·002,031t^3
	(*v*)	1932-33	Y	=	—2·586,976	+	0·568,367t	—	0·023,865t^2	+	0·001,014t^3

ıe values of x as calculated from the values of lerived from the linear, quadratic and the e equations with the help of the above tion were plotted along with the observed es. The curves for 1930 only are given in 2. It will be seen that the observed and the lated values of x have a similar trend and that ubic regression usually gave a much closer fit both the linear and the quadratic regressions.

Average polynomial curves. After having l the regression equations for the individual , it is now possible to calculate an average ıomial curve for each variety. Thus the tions due to environmental conditions from to year will be eliminated and the normal ge rate of flower production in each variety e found out. It will also then be possible to are the different varieties between themselves. order to find the trend of the average poly- al curve, the sum of squares for the average , quadratic and cubic regressions as well ose due to the heterogeneity of the seasonal s from the average regressions were cal- ed. The following method was employed is purpose.

If the polynomials for r seasons be represented as :

$$Y_1 = a_1 + b_1 x + c_1 x^2 + d_1 x^3 + \ldots\ldots\ldots + p_1 x^n$$

$$Y_2 = a_2 + b_2 x + c_2 x^2 + d_2 x^3 + \ldots\ldots\ldots + p_2 x^n$$

$$Y_r = a_r + b_r x + c_r x^2 + d_r x^3 + \ldots\ldots\ldots + p_r x^n$$

and the number of observations for the seasons be $N_1, N_2, N_3 \ldots\ldots\ldots\ldots\ldots\ldots N_r$, the above equations can be transformed as suggested by Tippett [1937] :

$$Y_1 = A_1 + B_1 T_1 + C_1 T_2 + D_1 T_3 + \ldots\ldots + P_1 T_n$$

$$Y_2 = A_2 + B_2 T_1 + C_2 T_2 + D_2 T_3 + \ldots\ldots + P_2 T_n$$

$$Y_r = A + B_r T_1 + C_r T_2 + D_r T_3 + \ldots\ldots + P_r T_n$$

The average polynomial of the nth degree would be given by :

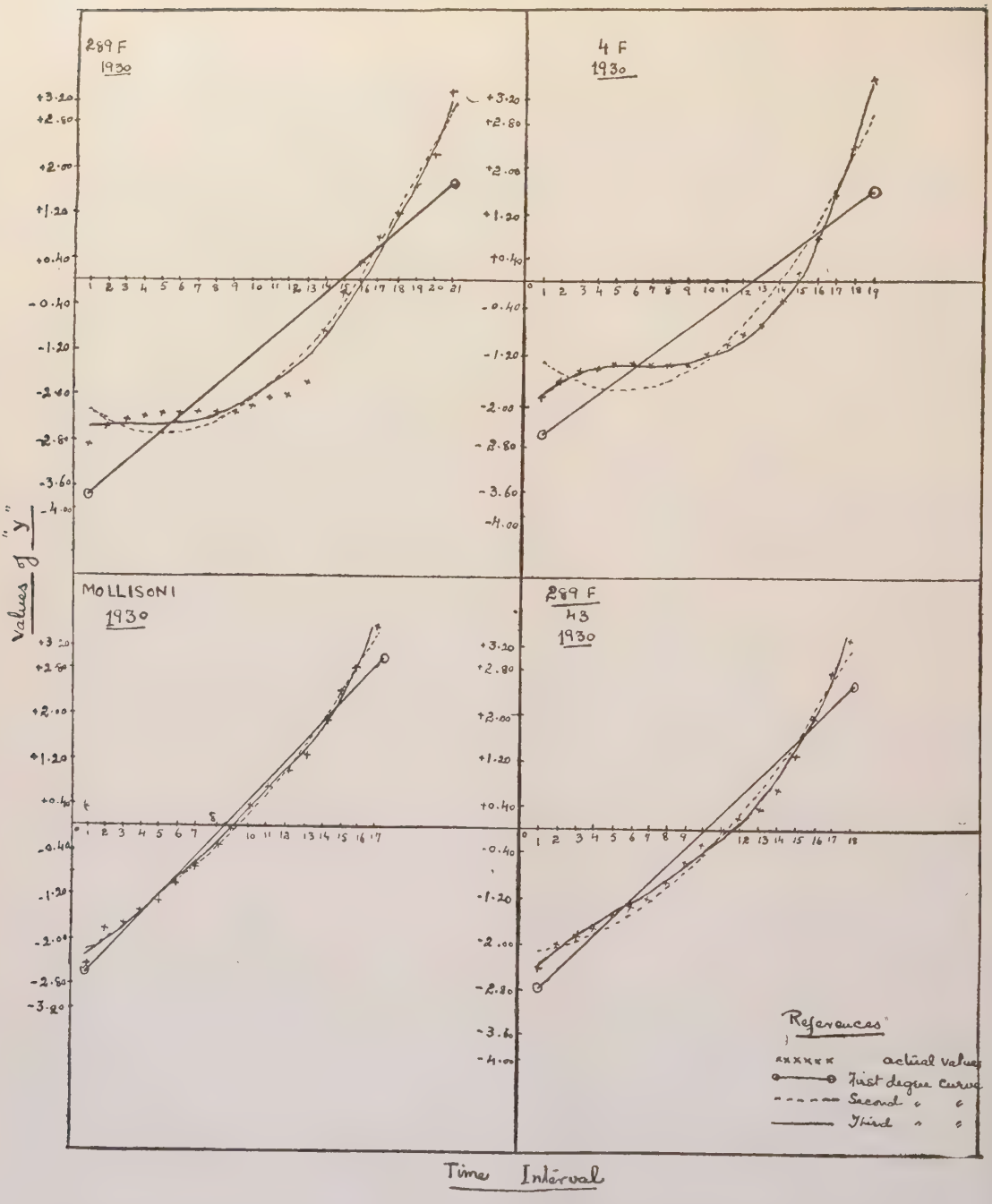

FIG. 1. Orthogonal polynomial curves and the actual values of 'y' for 1930

$$Y = A + BT_1 + CT_2 + DT_3 + \ldots\ldots\ldots\ldots + PT_n$$

where $A = \dfrac{\Sigma_1^r (\Sigma Y)}{\Sigma_1 N}$; $B = \dfrac{\Sigma_1 (\Sigma y T_1)}{\Sigma_1^r \dfrac{N(N^2-1)}{(12)}}$

$$C = \frac{\Sigma_1^r (\Sigma y \quad T_2)}{\Sigma_1^r \dfrac{N(N^2-1)(N^2-4)}{180}}$$

and similarly the other coefficient can be calculated.

A test of significance for the heterogeneity the regression curves can be made in a mar similar to that for the linear regression. For individual curve, the sum of squares for regresssion coefficient can be easily computed indicated below :

S. S. for linear regression $(B) = B^2 \left\{ \Sigma \dfrac{N(N^2-}{12} \right.$

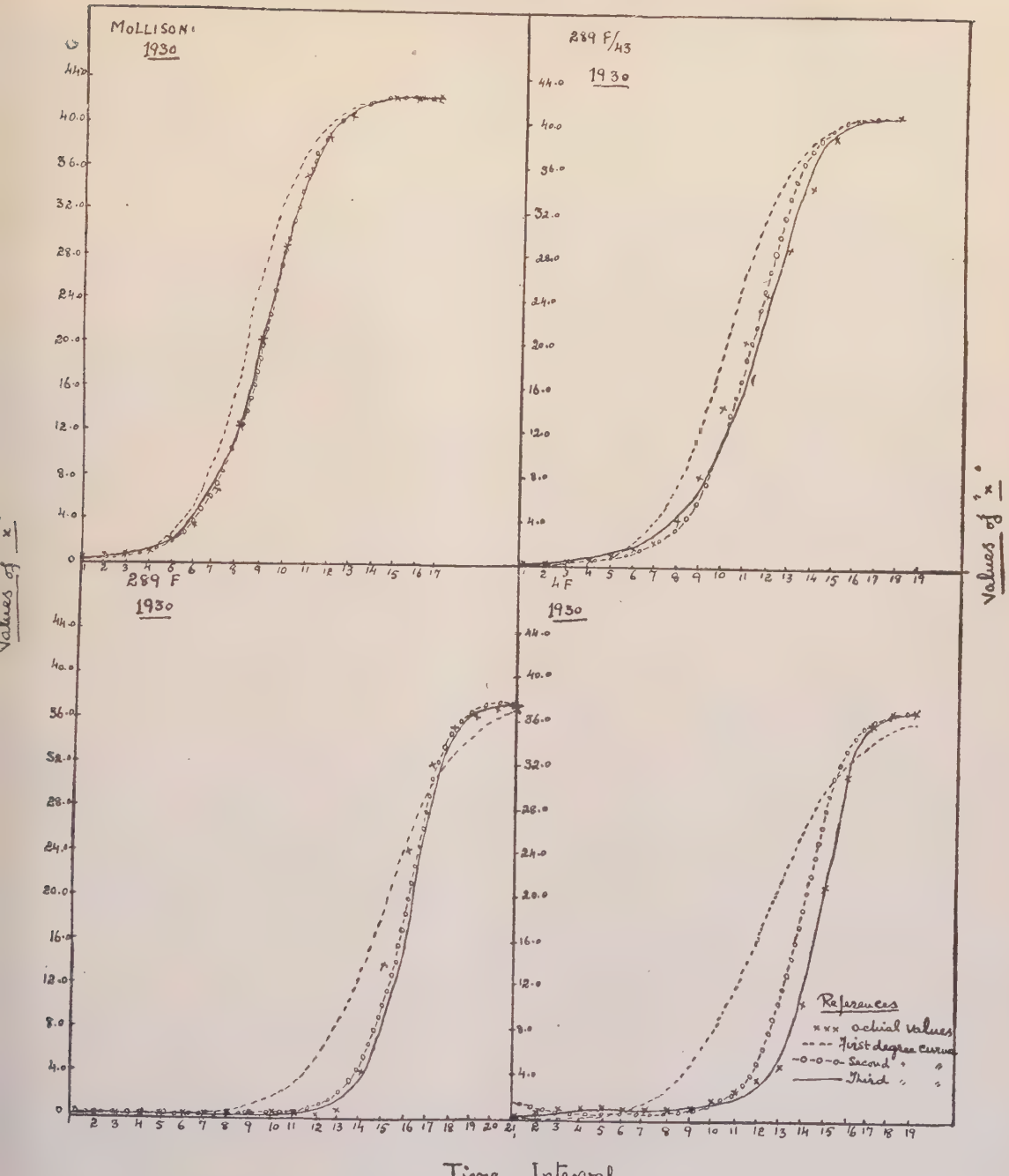

FIG. 2. Values of 'x' obtained from the polynomials and the actual data for 1930

S. S. for quadratic regression (C)

$$= C^2 \left\{ \Sigma \frac{N(N^2-1)\,(N^2-4)}{180} \right\}, \text{ etc.}$$

h corresponding to one degree of freedom. us for r seasons the total sum of squares for any regression coefficient will have r degrees of freedom out of which one will represent the sum of squares corresponding to the average curve and the remaining $(r-1)$ represent the deviations from the average curve. These may be tested against the residual sum of squares obtained by adding the residuals for the individual years.

The so transformed average curve can be converted into a polynomial in t in the same manner as was done for the seasonal curves. One fact that needs illustration is that the value of N was taken as the average of $N_1, N_2 \ldots\ldots\ldots Nr$ and in case it did not come out to be a whole number, a suitable change was made in the number of observations*.

The sum of squares of the average regression curves and the deviations are given in Table III.

It will be seen from Table III that the linear, quadratic and the cubic regressions as well as the heterogeneity between these regressions was significant except the average quadratic regression in 39 Mollisoni and the heterogeneity in the cubic regression in the case of 289F and 289F/43. The significance of the deviations of the yearly curves from the average curve indicates that the seasonal factors affect the rate of flower production of cotton at Lyallpur in a very large measure.

Looking at the mean squares, it is found that the linear component in all cases was overwhelmingly large as compared to the quadratic and cubic components, but as the cubic component was also significant, it may, therefore, be deduced that the average polynomial curve of the third degree would represent the normal rate of flower production of cottons at Lyallpur. The sum of squares due to the deviations from the average regression curves was comparatively less in 39 Mollisoni than in the American varieties. The yearly as well as the average polynomial curves for all the varieties are given in Fig. 3. The curves for 39 Mollisoni again indicate a very close similarity.

The third degree equations for all the varieties are given below :

289F $Y = -2{\cdot}521{,}570 + 0{\cdot}067{,}118t + 0{\cdot}006{,}383t^2 + 0{\cdot}000{,}271t^3$

4F $Y = -2{\cdot}778{,}472 + 0{\cdot}389{,}980t - 0{\cdot}027{,}300t^2 + 0{\cdot}001{,}174t^3$

289F/43 $Y = -2{\cdot}977{,}650 + 0{\cdot}470{,}095t - 0{\cdot}035{,}222t^2 + 0{\cdot}001{,}435t^3$

39 Mollisoni $Y = -2{\cdot}631{,}531 + 0{\cdot}533{,}466t - 0{\cdot}027{,}951t^2 + 0{\cdot}001{,}409t^3$

* The average polynomial can also be converted by employing the following formulae :

$$T_2 = (t-\bar{t})^2 - \mu_2 ; \quad T_3 = (t-\bar{t})^3 \frac{-\mu_4}{\mu_2}(t-\bar{t})$$

where $\mu_2 = \frac{\Sigma_1[\Sigma(t-\bar{t})^2]}{\Sigma N}$ and $\frac{\mu_4}{\mu_2} = \frac{[\Sigma^r{}_1 \Sigma (t-\bar{t})^4]}{\Sigma_1[\Sigma(t-\bar{t})_2]}$

where μ_2 and μ_4 are the second and the fourth moments of t.

The equation for 289F/43 was checked by this method and it worked out as follows :

$Y = -2{\cdot}969{,}744 + 0{\cdot}471{,}352t - 0{\cdot}035{,}751t^2 + 0{\cdot}001{,}435t^3$ which agrees very well with the equation obtained by the previous method.

Relative rate of flower production

The relative rate of flower production can be ascertained by differentiating the equation $Y = A + Bt + Ct^2 + Dt^3$ with respect to the independent variable t.

$$\frac{dy}{dt} = B + 2CT + 3Dt^2 ; \text{ but } Y = \log \frac{x}{a-x}$$

$$\text{Therefore } \frac{dy}{dt} = \frac{dx}{dt} \cdot \frac{a \log_{10}^e}{x(a-x)} = (B + 2Ct + 3Dt^2)$$

$$\text{or } \frac{dx}{dt} = \frac{(B + 2Ct + 3Dt^2)}{a \log} \cdot x(a-x)$$

Thus the deduced equation is comparable to equation (*iii*). From the analogy with the compound interest law, k in equation (*iii*) may be looked upon as the true or absolute rate of flower production corresponding to the rate of interest. The actual rate at any time depends upon k as well as the number of flowers already produced up to any particular time. The constant $K = a\,k \log_{10}^e$, which contains the element a probably characteristic of a variety may then be called the absolute rate of flower production for the variety.

On comparing the new equations for the rate of flower production with equation (*iii*), we find A comparable to $\frac{(B + 2Ct + 3Dt^2)}{a \log_{10}^e}$ and so K can easily be compared with $(B + 2Ct + 3Dt^2)$. Here it may be mentioned that Prescott [1922] found that the relative rate of flower production K, was constant for a variety over a season, but we have found that the relative rate of flower production was a function of time, witness the significant deviations from the linear regression. The equations for the relative rate of flower production from the average curves are given below :

289F $\frac{dy}{dt} = 0{\cdot}067{,}118 + 0{\cdot}012{,}676t + 0{\cdot}000{,}813t^2$

4F $\frac{dy}{dt} = 0{\cdot}389{,}980 - 0{\cdot}054{,}600t + 0{\cdot}003{,}522t^2$

289F/43 $\frac{dy}{dt} = 0{\cdot}470{,}095 - 0{\cdot}070{,}444t + 0{\cdot}004{,}305t^2$

39 Mollisoni $\frac{dy}{dt} = 0{\cdot}533{,}466 - 0{\cdot}055{,}902t + 0{\cdot}004{,}227t^2$

The average relative rates of flower production over the whole season calculated from the yearly equations of all the varieties are given in Table IV.

It will be seen from Table IV that the relative rate of flower production was higher in the case of indigenous variety (39 Mollisoni) as compared to the American varieties, which did not vary very much amongst themselves.

TABLE III

Sum of squares of the average regressions

Due to	4F			289F			289/F43			39 Mollisoni		
	D.F.	S. S.	M. S.	D.F.	S. S.	M. S.	D.F.	S. S.	M. S.	D.F.	S. S.	M. S.
Linear regression	1	306·492,685	306·492,685**	1	287·144,851	287·144,851**	1	132·860,100	132·860,100**	1	142·961,522	142·961,522**
Quadratic regression	1	8·644,306	8·644,306**	1	21·604,339	21·604,339**	1	2·844,704	2·844,7044**	1	0·032.522	0·032,522
Cubic regression	1	5·808,602	5·808,602**	1	1·969,913	1·969,913**	1	2·501,120	2·501,120**	1	0·297,346	0·297,346**
Deviations from average linear regression	6	20·306,501	3·384,416**	6	13·722,504	2·287,084**	2	11·526,764	5·763,382**	4	2·834,949	0·708,737**
Deviations from average quadratic regression	6	9·254,374	1·542,396**	6	3·494,590	0·582,432**	2	1·845,057	0·922,529**	4	1·045,407	0·261,350**
Deviations from average cubic regression	6	1·855,579	0·309,263**	6	0·436,628	0·072,771	2	0·104,139	0·052,069	4	0·238,668	0·059,667**
Residual	105	3·948,731	0·037,607	98	3·787,358	0·038,647	45	0·868,024	0·019,289	45	0·657,372	0·014,608
Total	126	356·310,777	...	119	332·160,183	...	54	152·549,908	...	60	148·067,779	...

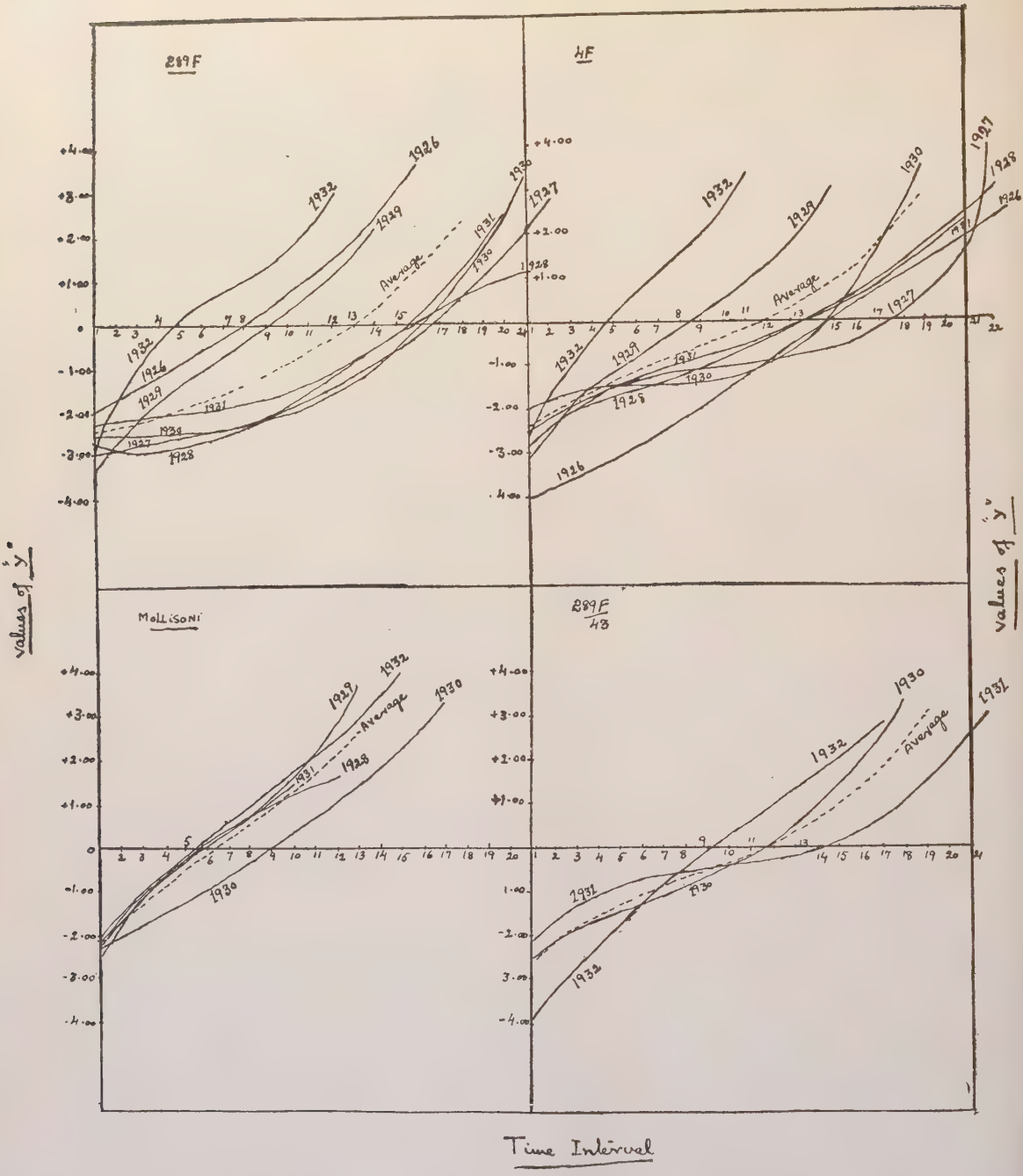

FIG. 3. Deviations of yearly polynomials from the average

A comparison of the indigenous variety, 39 Mollisoni, with the three acclimatized American varieties reveals that the fluctuations in flower production from year to year are far less in the indigenous variety as compared to the American strains. This means that 39 Mollisoni is more adapted to the local conditions than the American varieties.

GROWTH IN HEIGHT AND FLOWER PRODUCTION

It will now be interesting to compare the rate of growth in height with the rate of flower production. It has already been shown [Afzal and Iyer, 1934] that Mollisoni had a higher rate of growth in height and now we find the rate of flower production in this cotton is also higher than the American varieties. The correlation between the rate

TABLE IV

Average relative rate of flower production

Variety	1926-27	1927-28	1928-29	1929-30	1930-31	1931-32	1932-33
F . . .	0·0721	0·0518	0·0478	0·0789	0·0541	0·0456	0·0916
. . .	0·0596	0·0439	0·0490	0·0799	0·0476	0·0433	0·1102
F/43 . .	..	..	..	..	0·0611	0·0399	0·0793
lisoni . .	..	..	0·0666	0·0933	0·0687	0·0789	0·0830

rowth in height and flower production between leties ($n = 2$) was $r = 0{\cdot}9745$ which was ificant at 5 per cent level. This indicates that ı any particular variety X under experiment ny particular year, the rate of growth in height higher than in any other variety Y in the ıe year, the rate of flower production will also ıigher in X as compared to Y.

t will be well to speculate on this phenomenon erms of genes. It can be argued that the genes ponsible for the vegetative growth as well as se for the flower production attended by their s and minus modifiers are not assorted inde-dently of one another but are closely linked and therefore be considered to be located on the ıe chromosome in close proximity to one another. comparison of the rate of growth in height and ver production for any one variety in different sons, however, showed that the high rate of wth in height depressed the rate of flower duction. The values of the average efficiency ces (b) for height and the relative rate of flower duction (K) are plotted for each variety in 4.

will be seen from Fig. 4 that the peaks for two rates always stand face to face and there-it can be said that in any one year when the of growth in height was higher, the rate of er production was expected to be low. The elations worked out between these two co-ients within the American varieties and for lisoni were :

$r_{Am} = -0{\cdot}3011 \quad n = 13$

$r_{M} = -0{\cdot}6418 \quad n = 3$

lthough both these correlations were non-ificant, the negative trend is patent and the rates of growth herein dealt with were pro-ly opposed to one another. The high rate of etative growth meant a low rate of reproductive wth. This phenomenon is within the experi-e of the cultivator in the Punjab and in any one r when the cotton crop makes luxuriant vege-ve growth, the yield is decreased.

ince it has already been shown that the genes ponsible for vegetative growth and flower production lie close to one another on the same chromosome, the negative trend of the correlation between growth in height and flower production in any particular year may be ascribed to the differential effect of the environmental conditions on the behaviour in two genes. Conditions which allow full play to the effect of genes for vegetative growth partially inhibit the full manifestation of the effect of the genes for flower production.

SUMMARY

An attempt has been made to find out a mathematical expression for the flowering curves of four varieties of cotton grown at Lyallpur. It was found that the logistic equation of the third degree, viz. $\text{Log}\ \frac{x}{a-x} = A + Bt + Ct^2 + Dt^3$, gave the best fit for the rate of flower production. The average trend of flower production for a large number of years was also found to be significant to the third degree. The relative rate of flower production was found to be a function of time, although Prescott [1922] working on Egyptian cotton found it to be constant.

The relative rate of flower production was high for the indigenous variety, 39 Mollisoni, than for all the acclimatized Punjab-American varieties.

A comparison of the relative rate of growth in height and flower production showed that whenever the rate of growth was higher in any particular variety than in another in any one year, the rate of flower production was also higher in the former. In one variety, however, if the rate of growth was higher in any one year, the rate of flower production was low.

ACKNOWLEDGEMENTS

This work was done as a part of the Punjab Botanical Research Scheme financed jointly by the Indian Central Cotton Committee and the Punjab Government.

We are grateful to Mr V. B. Sahasrabuddhe, Statistical Assistant, Institute of Plant Industry, Indore, for having done a great deal of computation work for us.

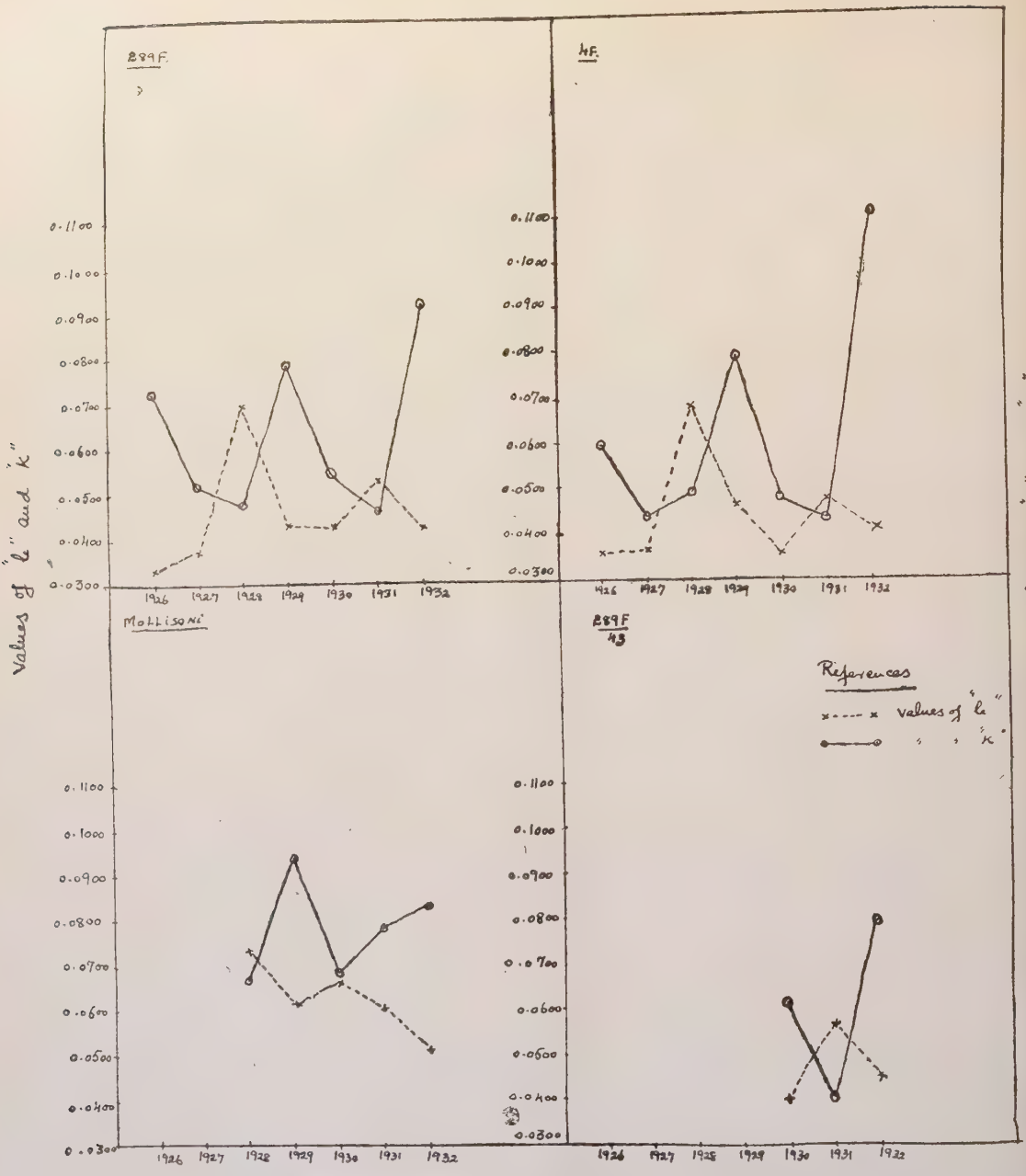

FIG. 4. The relation between the relative rates of growth in height and of flower production

REFERENCES

Afzal, M. (1941). *Second Conference of Scientific Research Workers on Cotton in India.* Indian Central Cotton Committee

———— and Iyer, S. S. (1934). A statistical study of the growth of main stem in cotton. *Indian J. agric. Sci.* **4**, 147

Bartel, A. T. and Martin, J. H. (1938). The growth curve of sorghum. *J. agric. Res.* 843

Blackman, V. H. (1919). The compound interest law and plant growth. *Ann. Bot.* **33**, 353

Fisher, R. A. (1936). *Statistical Methods for Rese Workers,* 5th Edition, Oliver and Boyd, London

Maskell, E. J. (1930). *First Conference on Cotton Grou Problems.* Empire Cotton Growing Corporation

Prescott, J. A. (1922). The flowering curve of the Eg tian cotton plant. *Ann. Bot.* **36**, 121

Tippett, L. H. C. (1937). *The Methods of Statistics,* Edition, Williams and Norgate Ltd. Great Ru Street, London

Trought, T. (1928). Non-dehiscence of anther Punjab-American cottons. *Mem. Dept. Agri. I Bot. Ser.* **17**, Pt. I

STUDIES IN THE PRESERVATION OF FRUIT JUICES

III. PREPARATION AND PRESERVATION OF TOMATO JUICE*

By Lal Singh, B. Sc. (Hons.), M.Sc. (Calif.), Fruit Specialist, Punjab and Girdhari Lal, Ph.D. (Lond.), D. I. C., Biochemist, Punjab Agricultural College, Lyallpur

(Received for publication on 12 April 1943)

ıato juice, a product of comparatively nt origin, was first introduced in the Ame- n market in 1929, and to-day it is by far mos popular juice. In 1929, only 165 thou- d cases (case of 24 No. 2 cans) were produced, reas due to the expanding consumers' demand pack rose to nearly 9 million cases in 1936 ion, 1936]. Tomato juice like grapefruit juice slyn and Marsh, 1937] was first produced as a ans of utilizing the waste from the tomato ning factories in America but at present, how- r, most of it is made from whole fruits.

n the Punjab, tomatoes are especially prolific he months of April, May and June and are also ilable in winter months if protected from frost. summer months they can be purchased at remely low prices of a rupee or so per maund of lb. (pre-war) and it was realized that such cheap it could be very profitably utilized for the prepa- ion of tomato juice.

Various methods for the manufacture of tomato e as practised in Western countries are dis- sed by Sanborn [1938], Cruess [1938, 3], Tressler 38], Pearce & Ruyle [1938], Anonymous [1931 ; 9], Joslyn [1937], Kohman [1931 ; 1934], and lyn and Marsh [1937]. The effect of different hods of preparation on the quality of the pro- t are also described. The equipment employed usually of automatic nature and is meant for ss production and is very expensive. In the uing investigation, however, an effort has been de to employ simpler type of equipment for duction on 'home' as well as semi-commercial le. Treatment of tomatoes prior to juice raction, preservation of juice by different hods, changes in theq uality of the product r about two years' storage at room temperature, t of production, etc. are discussed. As a conse- nce of a study of these factors, a method for the paration and preservation of the juice has been cribed.

Raw material

n the absence of any standard varieties of natoes, two types of tomatoes locally known as *desi* and *Peshawari* were used. The fruit of *desi* variety was medium large having a rather irregular outline and of flattened shape usually with corrugations near the stalk end. On the average 4 to 6 fruits weighed to a lb. The fruit of *Peshawari* variety was pear-shaped and was rather small in size weighing on the average 12 to 14 fruits to a pound. Fully mature fruit of deep red colour was used in the experiments described in the sequel and it was found, as stated by Joslyn and Marsh [1937], that small red fruits (*Peshawari* variety) gave relatively a product of better quality than the large-sized fruit (*desi* variety).

Experimental

In order to see the composition of tomato juice (packed in tin and glass containers) available in the market, five samples of the product manufactured by different firms, local and foreign, were analysed for their specific gravity, percentage of soluble solids, sodium chloride and total acidity (as malic acid). The data thus collected are given in Table I. Composition of these samples was kept as a basis for the preparation of experimental lots of tomato juice. In the product finally standardized, the total solids and sodium chloride content which are the main ingredients concerned with the 'body', taste and flavour of the juice, were controlled at a figure of 6·0 and 1·0 per cent respectively.

Table I

Analysis of various brands of tomato juice as obtainable in the local market

Brand of tomato juice	Sp. gravity of juice at 68°F.	Sp. gravity of filtrate at 68°F.	Per cent solids in juice	Salt as sodium chloride in 100 c.c. juice	Total acid as malic in 100 c. c. juice
1. Well-known brand (Foreign manufacture) 1936	1·0240	1·022	5·66	0·89	0·38
2. Ditto 1938	1·0240	1·022	5·66	0·79	0·36
3. Ditto . .	1·0334	1·031	7·99	0·84	0·49
4. Ditto . .	1·0250	1·023	5·91	0·82	0·38
5. Local manufacture	1·0387	1·036	9·27	1·742	0·59
6. Ditto . .	1·0292	1·027	6·95	1·111	0·56

*Parts I and II of this paper have appeared as Misc. l. Nos. 32 and 39 of the Imperial Council of Agricultu- Research

Preparation of juice

Tomato juice being a product of recent origin, no recognized standard method for its manufacture has so far been adopted. In Western countries, the method of manufacture varies from plant to plant [Joslyn and Marsh, 1937].

The method of manufacture of tomato juice essentially consists of :

1. Washing and sorting of fruit
2. Trimming of fruit
3. Pre-treatment of fruit prior to juice extraction
4. Extraction of juice
5. Packing and processing

Pre-treatment of fruit prior to juice extraction, methods of extraction of juice and its proper preservation are of prime importance and it is in the manipulation of these processes that opinions differ as to what methods yield the best juice.

1. *Washing and sorting of fruit*

Greatest possible care should be taken in washing the fruit thoroughly to remove dirt and other extraneous matter.

In experimental lots prepared in these laboratories to standardize the product, tomatoes were first soaked in a cement tank in running cold water and finally washed with strong sprays of water. The washed fruit was then sorted, over-ripe and under-ripe fruits were discarded as these yield a juice of poor flavour and colour [Cruess, 1938, 3].

Different types of washing equipment for large-scale production have been described by Joslyn and Marsh [1937] and Tressler *et al.* [1939].

2. *Trimming of fruit*

The fruit after washing and sorting should be carefully trimmed to remove stain, rotten and green or yellow portions, as the inclusion of these adversely affects the quality of the product.

3. *Pre-treatment of fruit prior to juice extraction*

In these laboratories, tomatoes prior to juice extraction, were subjected to the following treatments :

(1) Whole tomatoes (after washing and trimming) were blanched in boiling water for 3-5 min. and (2) tomatoes were ' broken ' or crushed as suggested by Lal Singh and Girdhari Lal [1940]—this briefly consisted of passing the trimmed tomatoes in a grape crusher. The crushed tomatoes were then boiled for 3-5 min. In both the treatments heating was done in a steam jacketed kettle [Lal Singh and Girdhari Lal, 1940]. Pre-heating of tomatoes almost completely extracted the colouring matter from the skin and at the same time rendered the fruit soft, thus facilitating the extraction of juice.

Results of a typical experiment carried out to test the efficiency of these two methods of pre heating the juice in the case of *desi* and *Peshawar* varieties of tomatoes are given in Table II. It wil be seen from this table that comparatively highe yields of juice were obtained in the case of chop ped or crushed tomatoes, viz. 64·4 per cent (*des* variety) and 70·0 per cent (*Peshawari* variety) a against 53·0 per cent and 65·0 per cent obtained when tomatoes were blanched as wholes.

Table II

Results of pre-treatment of tomatoes prior to juice extraction

Treatment	*Desi* tomatoes			*Peshawari* tomatoes		
	Yield of juice per cent	Sp. gr. of filtrate	Per cent solids in juice	Yield of juice per cent	Sp. gr. of filtrate	Per cent solid in juic
1. Whole tomatoes blanched in boiling water for about 3-5 min. before extraction	53·0	1·0205	5·27	65·0	1·0228	5·
2. Tomatoes crushed in cold and boiled for 3-5 min. before extraction	64·4	1·0240	6·16	70·0	1·049	6·

Blanching of whole tomatoes which wou naturally include some trimmed or cut tomatoe therefore, suffered from an obvious disadvanta in so far as some juicy portion of the fruit from th cut surface diffused into the blanching vesse resulting in loss of some juice as indicated in th experiment mentioned above. This loss can b considerably avoided if whole tomatoes aft trimming are scalded in steam.

Cut-out examination of the two sets of jui prepared under treatments (1) & (2) in Table I carried out during a storage period of about tw years, revealed that the tomatoes crushed an boiled for 3-5 min. yielded a much superior pr duct in respect of ' body ', flavour and taste to th obtained by blanching the whole tomatoes.

In regard to the effect of pre-treatment crushed tomatoes prior to juice extraction on i vitamin content and viscosity, various workers the tomato juice line like Tressler *et al.* [193 Sanborn [1938], Tressler [1938], Joslyn [1937] an Cruess [1938, 1], have put forth their views fro time to time. Recommendations made by the workers clearly indicate the usefulness of pr heating the crushed tomatoes before juice extra tion, although diversity of opinion exists as whether the fresh tomatoes should be scalded blanched as wholes or as pieces.

uice extraction

one of the extractors like the 'Indiana Juice hine' [Tressler, 1938] and the 'non-aerating extractor' [Anonymous, 1939] normally used he extraction of tomato juice were available ng the course of this investigtion. Conse-tly the best use had to be made of the equip-t available. During the preliminary stages of work, the tomatoes under two treatments le II) were screened through galvanized iron (1 mm. mesh) covered with a thin muslin [Lal Singh and Girdhari Lal, 1940]. Ordi-y to avoid metallic contamination, non-odible metal screens like those of monel metal, less steel, etc. should be used, but due to the availability of these, the use of galvanized sieves could not be avoided—this, however, not materially affect the quality of the product ng storage.

the final stages of standardizing this product, ever, modern 'fruit pulping machine' [Lal h, Girdhar Lal & Ishaq, 1943] was available for acting the juice. This machine is entirely e of stainless steel and has been found to be efficient for the extraction of juice from pre-ed tomatoes. The juice extracted by the ing machine has been found to yield a product excellent quality. This machine is now being very satisfactorily for semi-commercial pro-ion and is capable of extracting juice from t 40 maunds tomatoes, per eight hour work-lay.

acking and processing of tomato juice

ice passing through the pulping machine was ediately raised to boiling point in steam-eted kettles. At this stage a quick test was for determining the total solids content ess and Christie, 1922], which was found to ar about 6·0 per cent in the typical large-experiment (Table II).

dium chloride content was maintained at 1·0 ent level by adding common salt just after ng the juice prior to filling. A few prelimina-xperiments on the preparation of tomato on a small scale indicated that addition of t one per cent cane sugar in combination with non salt considerably enhanced the flavour taste of the juice. Crystalline cane sugar at bove rate (i.e. 1·0 per cent) was added. It hen filled at a temperature of 180°-190° F. in ze cans as well as 24 oz. capacity crown top es, the two types of containers being sealed e usual manner and processed as follows:

A2 cans—25 min. at 212° F.

24 oz. bottles—35 min. at 212° F.

e containers were then immediately cooled in ng water.

The juice pasteurized and packed in the above manner remained in sound condition even after a storage of about one and a half years, but had one obvious disadvantage that it spoiled within a few hours after opening of the containers as would naturally be the case in any pasteurized sub-acid and unsweetened fruit or vegetable juice. To overcome this difficulty, further experiments were conducted in June 1941. In these experiments chemical preservation by sodium benzoate (in doses of 0·02, 0·05 and 0·1 per cent) in combination with pasteurization was tried, to test whether the keeping quality of tomato juice, after opening the containers, could be improved. This trial indicated that juice preserved chemically by 0·02 and 0·05 per cent sodium benzoate and then pasteurized, had normal taste and that the juice after opening the containers remained in good sound condition for over two months in the laboratory.

There is considerable difference of opinion concerning the methods of packing and processing of tomato juice amongst workers in foreign countries. In this connection interesting observations have been made by workerss like Cameron [1936, 1], Tressler [1938], Pearce and Ruyle [1938], Tressler *et al.* [1939]. They have also outlined different types of packing and processing equipment for large-scale production.

Colour changes in the juice

During the processing and storage of tomato products, the browning of their typical bright red colour is not an uncommon observation. No one has yet satisfactorily explained the causes of this browning, although several possibilities have been put forth by Matlack and Sando [1933].

Literature on the comparative reaction of glass and tin containers on the red colour of tomato products is scanty. In a preliminary experiment conducted in these laboratories in 1937, in which juice from one lot was packed separately in ordinary white glass crown-corked bottles, and in plain and lacquered cans, the following observations were made during a storage period of 1½ year at room temperature.

1. The light red colour of the juice in glass bottles was stable for six to eight months and then gradually changed to deep brown, the intensity of brown colour varying considerably in individual bottles.

2. The juice in tin containers retained its normal bright-red colour during the entire storage period, but acquired a slightly tinny flavour and taste which was not unpleasant. In lacquered cans, however, it became bitter and the lacquer of the can though intact, was almost completely separated from the tin plate and came off even with a slight

touch after the can had been emptied of its contents.

These adverse colour changes in the juice packed in glass may be attributed to, (1) the composition of glass, i.e. its alkaline nature due to the presence of calcium and sodium silicates (as it was observed that addition of even a trace of a week alkaline solution to the freshly prepared tomato juice turned its colour brown), (2) the effect of light, and (3) the effect of air present in the head-space in the bottle.

Further critical study of these colour changes was made in 1939. In these experiments, juice was packed in five different types of bottles of different makes and also in plain tin cans. The glass of each type of bottles was presumed to have different chemical composition. In each of the bottled lots, a few bottles were also covered with black wrappers to cut off the action of light.

Examination of the above sets during one year's storage showed that :

(1) Irrespective of the type of the glass of the bottles of different makes, the juice in some became gradually brown, whereas in others, the change of colour from bright red to brown was not so marked.

(2) Cutting off light had no effect on the colour of juice.

(3) Canned tomato juice retained its normal bright red colour to a marked degree.

From the above, it would seem, therefore, that the colour changes in the bottled and canned tomato juice are probably controlled by the amount of oxygen incorporated in the juice during the process of manufacture. In the case of canned product, oxygen is rapidly fixed by the tin plate [Joslyn and Marsh, 1937], thus resulting in the least change in the colour of the canned juice, whereas in the bottled juice it seemed that varying amounts of oxygen in the air (perhaps incorporated while packing) in the juice affected corresponding change from bright-red to dark brown, as in this case, oxygen is free to oxidize the colour and is not fixed by glass as in the case of tin can.

Carotene and ascorbic acid content

With the equipment available in these laboratories, an attempt was made to determine the loss of carotene and ascorbic acid during different stages of the manufacture of tomato juice (Table III). Tomatoes while passing through five different stages of manufacture, viz. crushing, boiling, sieving, (to remove seeds and skin), heating and finally pasteurizing, were sampled at each stage on four different days for the determination of carotene and ascorbic acid content. Carotene was determined colorimetrically in a Lovibond tintometer employing Steenbock and Boutwell's [1920] method for extraction of carotene, and vitamin C was determined by 2 : 6 dichlorophenol-indophenol by the method of Birch Harris and Ray [1933].

Table III

Loss of carotene and ascorbic acid in tomato ju

Sample	31 May 1939	2 June 1939	3 June 1939	5 Ju 193
Carotene content in mg. per kgm. (1,000 gm.) of tomato juice				
I. Crushed	182·4	180·0	211·2	22
II. Boiled	139·2	110·4	141·6	15
III. Sieved	136·8	105·6	134·4	15
IV. Heated	134·4	105·6	134·4	15
V. Pasteurized	134·4	108·0	132·0	15
Vitamin C mg. ascorbic acid/100 gm. of juice				
I. Crushed	13·85	15·02	16·76	..
II. Boiled	12·41	13·46	12·82	..
III. Sieved	5·27	4·56	4·93	..
IV. Heated	2·68	3·11	3·61	..
V. Pasteurized	3·78	5·01	4·82	..
VI. A well-known foreign brand	...	...	3·72	..

It is seen from Table III that carotene is fa stable to the action of heat and oxidation by during the various stages of manufacture, whe a considerable loss of vitamin C occurs, particul when the juice is screened through sieve—a pro which takes a long time and is responsible incorporation of a fair amount of air in the prod resulting in the oxidation of ascorbic acid. Th observations are in agreement with those recor by workers like Sanborn [1938], Kohman [19 1931], Cruess [1938 ; 1, 2], Joslyn and Marsh [19 Kohman *et al.* [1930, 1933], and Fellers and B [1941] who have shown that in tomato juice ox tion by air is chiefly responsible for losses in col flavour and vitamins B and C—while vitamin fairly stable under usual process conditions b removed by filtration.

An interesting phenomenon was observed in last and the final stage of manufacture, pasteurization. In the pasteurized juice a c paratively higher ascorbic acid content was pre than in the same juice at a previous stage of ma facture, i.e., heating prior to filling and paste ing. This may be due to the partial reversio oxidized ascorbic acid to its active form when juice was subjected to final heating in a closed tainer. It will be interesting to note that M [1936] observed apparent increase by hea samples of plant tissues before and after traction in an aqueous medium due to the inac tion of enzyme (ascorbase). Mack and Tre [1937] explained the apparent increase of asc acid after heating the plant tissues to the forma of physiologically inactive degradation produ

reducing nature due to the decomposition of ydro-ascorbic acid. Reedman and Mac Henry 38] observed a similar increase on heating some etables, but found that the ascorbic acid libera- from the 'protein complex' was physiologi- y active and reduced the indicator.

From the above observations it would appear t unless special equipment is used to prevent incorporation of air during the entire manufac- ing process, a considerable loss in vitamin-C tent of tomato juice would take place, whereas amin A with ordinary equipment would remain ly stable.

General recommendations

During all stages of handling, from the extrac- n to the final packaging, the juice should be tected from contamination with metals, such zinc, lead, copper, iron, etc. as salts of these tals are toxic. Stainless steel, aluminium, kel, glass-lined equipment, nickel-copper alloys e monel metal can be safely used.

As a result of the investigation reported above, following methods for the preparation and pre- vation of tomato juice is recommended both home as well as commercial scale.

Step I. Take fully ripe, red-coloured tomatoes, sh thoroughly and trim carefully green and ten portions, if any.

Step II. (*a*) Home-scale production. Crush prepared tomatoes with a wooden ladle in a n-corrodible vessel. Boil the crushed mass in open aluminium vessel on direct fire for 3-5 nutes. Strain through a sieve of 1 mm. mesh de of nickel, monel metal or stainless steel. is preferable to cover the metallic sieve by a n muslin cloth. Heat the strained pulp in an en aluminium pan on direct fire and just bring to quick boil. Avoid over-heating. Remove pan from the direct fire.

(*b*) Semi-commercial production. Crush the ted and trimmed tomatoes, by passing them ough a crusher consisting of two revolving ustable grooved wooden rollers placed hori- tally. For removing seeds and skin, pass the shed mass through a pulping or straining chine [Lal Singh, *et al.* 1943]. Heat the strained ce in a steam-jacketed kettle. Bring it to a ck boil, and cut off the steam.

f the right type of raw material is used, the ve process yields a product of the right consis- cy, but in case slightly over-ripe fruit is used, juice obtained may be too thick, in which case, s diluted with an appropriate amount of water ly a very small amount of water is required to added), so that the finished product contains ut 6·0 per cent total solids.

Total solids are determined as under. Strain the juice through a thick cloth and determine the specific gravity of the strained juice at 68° F. by a hydrometer. Read the percentage of total solids in the pulp corresponding to the observed specific gravity from the table given in text-books [Cruess, 1938, 3] on the subject.

Step III. To the heated juice as obtained under (*a*) and (*b*), add common salt, and sodium benzoate, dissolved in a small quantity of juice at the rate of one part and 0·02 part by weight, respectively, per 100 parts of juice. Pour the juice while hot in plain tin cans or in sterilized bottles and seal them air tight. Place the bottles or cans in a vessel having a false bottom, cover with water and keep the water boiling for half an hour. Cooking tanks of galvanized iron sheet with steam feed are available for use in large-scale production. Cool the bottles or cans by slowly displacing hot water by running cold water in the cooking tank. This will avoid cracking of bottles. Remove the bottles and cans and store them in cool and dry place.

Crown top bottles should be preferably used for bottling tomato juice; crown cork before use should be sterilized in boiling water for a few minutes. These instructions if strictly adhered to would minimize spoilage known as 'flat sour' giving the product a flat, medicinal flavour which is rather difficult to detect and is caused by thermophilic bacteria.

Cost of production

Cost of production as worked out on the basis of the data collected from the semi-commercial trials conducted over a period of three years, viz. 1939-1941, is summarized in Table IV.

Rates of purchase of raw material, bottles, etc. showed considerable fluctuations from year to year. The above does not include (1) charges on account of supervision and depreciation of machinery, (2) prices at present which have increased considerably on account of war would increase the cost of production proportionately.

Summary

A critical study has been made on the following aspects of the manufacture of tomato juice, viz. (*a*) varieties of tomatoes suitable for juice making. (*b*) washing and sorting of fruit, (*c*) trimming of fruit, (*d*) pre-treatment of fruit prior to juice extraction, (*e*) extraction of juice, (*f*) packing and processing, (*g*) colour changes in the juice as affected by glass and tin container, and (*h*) carotene and ascorbic acid content of juice as affected at different stages of its manufacture. Results are briefly summarized as below:

Fully mature and highly coloured fruits of *Peshawari* variety of tomatoes (fruit rather small

TABLE IV

	Amount	Price	Remarks
		Rs. A. P.	
1. Tomatoes . .	77 md 33 sr.	225 12 3	Average price of tomatoes per maund in 1939, 1940 and 1941 was Rs. 2-1-3, Rs. 3-4-5 and Rs. 5-2-9, respectively.
2. Common salt .	22·5 Sr.	2 4 9	
3. Coal (for boiler) .	71 md.	51 9 5	
4. Containers (24 oz. bottle)	2237	335 9 10	Average price of bottles per dozen in 1939, 1940 and 1941 was Rs. 1-10-0, Rs. 2-0-3 and Rs. 1-12-0 respectively.
5. Labour . .	...	62 12 0	
6. Labels, wrapper, screw, caps and corks	...	56 6 6	
7. Incidental charges like breakage, gloves, soap, cloth, etc.	...	74 5 0	
Total cost for 2237 bottles	...	808 11 9	
Cost per bottle (24 oz.)	...	0 5 9	

and of regular oval shape) gave comparatively a product of better quality than *desi* variety (fruit rather large, round and of irregular shape). In general, the variety of tomato to be used should be ' juicy ' rather than ' mealy '.

In a typical experiment, crushing and chopping the tomatoes prior to juice extraction gave higher percentage of juice than that obtained when whole tomatoes, trimmed to remove undesirable portions, were blanched in water, yielding a product much superior in respect of body, taste and flavour to that obtained by blanching whole tomatoes.

About 6 per cent total soluble solids in the juice gave a desirable product. Addition of about 1·0 per cent cane sugar greatly improved the taste and flavour of tomato juice.

Pasteurization in combination with chemical preservation (0·02 to 0·05 per cent sodium benzoate) was found to be the best method of preservation. The juice thus preserved and opened from time to time in the laboratory did not show any signs of spoilage for over two months, whereas juice preserved by pasteurization alone spoiled within a few hours of opening the container.

Colour changes in tomato juice during storage seemed to be controlled by the amount of oxygen or air incorporated in the juice during its different stages of manufacture. Canned juice retained its normal bright-red colour during a storage of about two years. The bottled product, however, showed a browning of varying degrees in different bottles, which was probably due to the corresponding varying amounts of air and oxyg incorporated while packing individual bottles.

Wrapping the bottles with black wrappers to c off the effect of light had no advantage in arrestir the adverse colour changes during storage.

Carotene was fairly stable to the action heat and oxidation during the different stages manufacture, whereas considerable loss occurred ascorbic acid content by oxidation, particular after sieving the heated tomatoes to remove see and skins.

Finally a method for the manufacture of toma juice on ' home ' as well as ' commercial ' scale h been described. On the basis of semi-commerci trials conducted over a period of three years, vi 1939-1941, the cost of production, excluding supe vision and depreciation charges worked out at annas and 9 pies per unit of 24 oz. bottles.

ACKNOWLEDGEMENT

The financial assistance of the Imperial Coun of Agricultural Research for a scheme of resear on the preservation of fruits and vegetables in t Punjab, under which the above investigation carried out, is gratefully acknowledged.

REFERENCES

Anonymous, (1931). Vitamins in tomato produ *Food Manufacture* **6,** 7

———— (1936), Record tomato juice pack predic *Fruit Products J.* **16,** 79

———— (1939). Preparation of tomato juice. *Imp. Inst., London* **37,** No. 4, 557

Birch, J. W., Harris, L. J. and Ray, S. N. (1933). A mi chemical method for determining the hexuronic (vitamin C) content of food stuffs, etc. *Biochem.* **27,** 590-94

Cameron, E. J. (1936, 1). Bacterial count in tom juice canning. *Canning Trade* **58,** 7-8, 28 (orig not seen)

Cruess, W. V. (1938, 1). Enzymes of fruits and vegeta *Fruit Products J.* **17,** 199-202

———— (1938, 2). The vitamin. *Fruit Products* **17,** 261-3

———— (1938, 3). *Commercial fruits and vegetable ducts, (Chapter on Tomato Products).* McGraw Book Co., New York

———— and Christie, A. W. (1922). *Laborat Manual of Fruit and Vegetable Products.* McG Hill Book Co., New York

Feller, C. R. and Buck, R. E. (1941). Retention of V min C. & A. in glass-packed foods. *Food Research* 135-41

Joslyn, M. A. (1937). Retaining flavour and vita content in fruit juices. *Fruit Products J.* **16,** 23

———— and Marsh, G. L. (1937). Commer production of fruit juices. *Univ. Calif. agri. E Sta. Calif. Cir.* **344,** 16-2

Kohman, E. F. (1931). Retaining vitamins in tom juice manufacture. *Food Industries* **3,** 263-4

hman, E. F. (1934). Progress in tomato juice manufacture. *Canning Trade* **57**, 13 (Original not seen)

——— (1937). Influence of canning procedure on vitamin C content of tomato juice. *Canning Trade* **59**, 16, 18 (Original not seen)

——— *et al.* (1930). Vitamins in tomato products. *J. Ind. & Eng. Chem.* **22**, 1015–8

——— (1933). Canning tomato juice without vitamin C loss. *J. Ind. & Eng. Chem.* **25**, 682-4

l Singh and Girdhari Lal (1940). Studies in the preservation of fruits and vegetables—an investigation on the methods of preparation and standardization of tomato ketchup. *Imp. Coun. agric. Res., India, Misc. Bull.* **31**

——— and M. Ishaq, (1943). Preparation and preservation of mango squash. *Indian Fmg.* **4**, 831-4

ck, G. L. (1936). The state of ascorbic acid in plant tissues. *Nature* **138**, 505-6

Mack, G. L. amd Tressler, D. K. (1937). Vitamin C in vegetables. *J. Biol. Chem.* **118**, 735-42

Matlack, M. B. and Sando, C. E. (1933). Colour in tomato products. *Fruit Products. J.* **13**, 81-2, 90

Pearce, W. E. and Ruyle, E. H. (1938). Relation of plant equipment to flat sour spoilage in tomato juice. *Fruit Products J.* **17**, 203-5, 219

Reedman, E. J. and McHenry, E. W.(1938). Combined ascorbic acid in plant tissues. *Biochem. J.* **32**, 85-93

Sanborn, N. H. (1938). Conservation of Vitamin C in tomato juice production. *Fruit Products J.* **17**, 164-5

Steenbock, H. and Boutwell, P. W. (1920). Fat soluble vitamins. *J. Biol. Chem.* **42**, 131-52

Tressler, D. K. (1938). Fruit and vegetable juices *Fruit Products J.* **17**, 196-8, 210

——— Joslyn, M. A. and Marsh, G. L. (1939). *Fruit* and *Vegetable Juices*. New York

CITRUS ROOTSTOCK TRIALS IN THE PUNJAB

I. THE INFLUENCE OF DIFFERENT ROOTSTOCKS ON THE VIGOUR OF BLOOD RED ORANGE

By Lal Singh, B. Sc. (Hons.), M. Sc. (Calif.), Fruit Specialist, Punjab, Lyallpur
and Sham Singh, B.Sc. (Agri.), Ph.D. (Bristol), Assistant Horticulturist, Punjab, Lyallpur

(Received for publication on 24 June 1942)

(With Plate I and one text-figure)

NCE the first publication in this series [Lal gh and Sham Singh, 1942], results of the luence of citrus rootstocks on another scion riety have been studied. These results throw ther light on the so-called rootstock influence, ich has been discussed already while review- literature on the subject in the previous mmunication. It may be added that Blood d being one of the most important varieties sweet orange grown, and its response to ious rootstocks especially in the prebearing ge being of sufficient economic importance d academic interest, the publication of the ults at this stage of the experiment is amply tified.

The data reported here were collected on the material planted at the Horticultural Research Sub-Station, Montgomery in February 1937 and cover the period from 1937 to 1942.

Material and layout

The rootstock material of the same age and vigour, which was raised both from seed and cuttings, was budded with Blood Red scion in February, 1936. The budded trees were planted up in the orchard in February 1937 by the randomized block method [Fisher, 1935]. Other details regarding the preparation of material and the layout were the same as already reported upon previously [Lal Singh and Sham Singh, 1942]. The various scion-stock combinations under study are given in Table I.

Table I

The different scion combinations under trial

ld No.	Method of raising the rootstock	Name of scion-stock combination	No. of trees under study	English equivalents of root-stocks	Specific names
3	Seed.	Blood Red on *Kharna khatta*	18	Nil	*C. karna* Raf.
,,	,,	Blood Red on *Jatti Khatti*	18	Rough lemon	*C. limonia*, Osbeck.
,,	,,	Blood Red on *Mitha*	18	Sweet lime	*C. aurantifolia* Var. Swingle
,,	,,	Blood Red on *Mokari*	18	Citron	*C. medica* Linn.
11	Cuttings	Blood Red on *Kharna Khatta*	18	..	..
,,	,,	Blood Red on *Jatti Khatti*	18	..	..
,,	,,	Blood Red on *Mitha*	18	..	..
,,	,,	Blood Red on *Jullunduri Khatti*	18	Smooth lemon	*Citrus Sp.*

It is clear from the foregoing that the experimental material constituted two sets: In the one case the Blood Red scion was budded on rootstocks raised from seed and, in the other, the same scion was budded on rootstocks propagated by the rooting of cuttings. The two groups of experimental material, thus prepared, were planted separately in two fields and treated as two independent and self-contained experiments. The results of both the trials are embodied in the present communication with a view to study the response of Blood Red trees growing on rootstocks, propagated both from seed and cuttings.

Data collected

Girth measurements of all the trees, correct to the nearest millimetre, were taken at a fixed point above the union year after year for the six-year period from 1937 to 1942. The idea in making these measurements was to study the vigour and rate of growth of Blood Red trees as influenced by the rootstocks on which they were stem-budded.

The data for 1937 relate to the behaviour of one year old 'nursery trees' as at the time of planting in the orchard, those for 1938 as the behaviour of one year old 'orchard trees' and those for 1942 as the behaviour of five year old orchard trees. The year-to-year circumferential measurements of Blood Red trees, as influenced by rootstocks in both the trials are compiled separately in Tables II and III.

Table II

The performance of Blood Red trees growing on certain rootstocks propagated from cuttings

Method of propagation of rootstock	Year of observation	Age of trees in the orchard	Average circumferential measurements in cm. for various rootstocks			
			Kharna khatta	Rough lemon	Sweet lime	Smooth lemon
Cuttings	1937	Pre-orchard	3·15	3·17	2·98	2·40
,,	1938	One year	5·02	4·96	4·29	3·64
,,	1939	Two years	9·70	9·71	7·42	6·28
,,	1940	Three years	14·40	16·30	12·1	10·70
,,	1941	Four years	17·2	23·6	16·5	16·5
,,	1942	Five years	20·0	31·5	21·4	23·1

Table III

The performance of Blood Red trees growing on certain rootstolks propagated from seed

Method of propagation of rootstock	Year of observation	Age of trees in the orchard	Average circumferential measurements in cm. for various rootstocks			
			Kharna khatta	Rough lemon	Sweet lime	Citron
Seeds	1938	One year	2·53	3·34	2·97	3·70
,,	1939	Two years	5·16	6·68	5·40	5·45
,,	1940	Three years	10·07	12·52	9·05	8·62
,,	1941	Four years	14·7	19·2	13·8	12·7
,,	1942	Five years	19·1	27·1	18·8	15·8

Methods employed

The mean figures for girth as influenced by different rootstocks are compiled in Tables II and III. The data show the yearly development of Blood Red trees, which depends upon (*a*) inherent growth capacity of the trees in association with various rootstocks technically known as 'relative growth rate' and (*b*) the seasonal and other accidental variations obtaining from year to year. Therefore, to make an exhaustive and accurate study of the developmental data collected, both aspects of the problem were duly considered.

To study growth rate, the logrithmic values of the girths taken at different intervals were calculated and plotted. The curves, so obtained, are shown graphically in Fig 1. These curves, being linear, are best studied by the exponential equation $W_1 = W_{oe}^{rt}$ which was devised by Blackman [1919] and subsequently used widely by several workers [Afzal and Iyer, 1934].

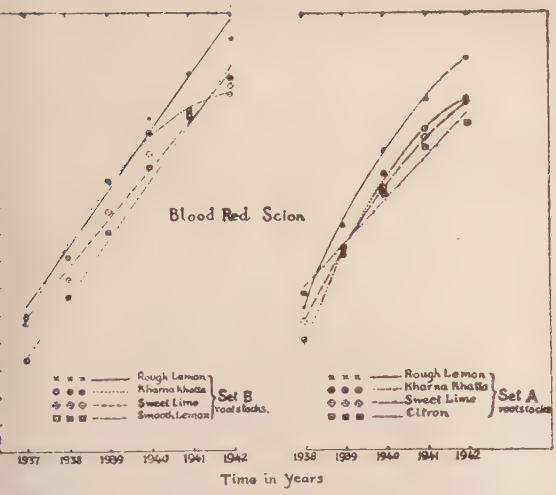

FIG. 1

The notation of the above equation used here as:

$Y = Ae^{bT}$, where

Y = girth in cm.

A = theoratical girth at the start in the hard

T = time in years from the beginning of the eriment

b = relative rate of growth per year

The above equation can be transformed as ler:

$$\text{Log}_{10} X = \log_{10} A + bT \log_{10} e$$
$$= \log_{10} A + b.\ \log_{10} e\, T$$

or $y = a + KT$ where, $a = \log_{10} A$

and $b = \dfrac{K}{\log_{10} e}$.

PRESENTATION AND DISCUSSION OF RESULTS

(A) *Comparison of data in Tables II and III*

A cursory comparison of the data in Tables II I III brings out prominently the fact that ood Red trees on rootstocks propagated from ttings (Table II) remained bigger-sized during the first five years than the corresponding trees on rootstocks raised from seed (Table III). At the time of planting in the orchard, in 1937, one year old trees on rootstocks raised from seed were so thin that their girth measurements could not be recorded by steel tape. And even after five years of their existence in the orchard (1942-data) the trees on rootstocks raised from cuttings remained bigger-sized than those on rootstocks raised from seed. This showed that initial advantage of vigour in case of rootstocks raised from cuttings persisted even after five years of orchard life, although, as would be seen later under item (*C*), the trees on seedling rootstocks are likely to outgrow those on cutting rootstocks in view of their higher rate of growth.

(B) *The yearly growth increment in girth*

The yearly growth increment in girth made by Blood Red trees in both the experiments was identical and interesting. Therefore, in the interest of brevity, the data for trees on rootstocks raised from cuttings alone are given in Table IV for detailed discussion.

The data for 1937 (col. 3, Table IV) collected at the time of planting the trees in the orchard, showed that in the pre-orchard or nursery stage, the Blood Red trees on rough lemon and *kharna khatta* made better growth than on the remaining two rootstocks. The data for 1938, being the year immediately following the transplanting of trees in the orchard, showed that there had been a considerable set back to growth on all the rootstocks. This happened mainly due to the fact that the trees took considerable time to settle down in new environment and to regenerate enough root system to put on new growth. However, the shock of transplantation appeared to be borne equally well by all the rootstocks as the growth, made during that year, was in the same order as that made in the preceding year. Furthermore, the root system of large-sized nur-

TABLE IV.

The mean annual increment in girth in cm. Scion variety—Blood Red

Growing season	Age of trees in the orchard	Year of observation	Rootstocks			
			Kharna khatta	Rough lemon	Sweet lime	Smooth lemon
936 . .	Pre-orchard . . .	February 1937 . .	3·15	3·17	2·98	2·40
937 . .	One year . . .	February 1938 . .	1·87	1·79	1·31	1·24
938 . .	Two years . . .	February 1939 . .	4·68	4·75	3·13	2·64
939 . .	Three years . . .	February 1940 . .	4·70	6·59	4·68	4·42
940 . .	Four years . . .	February 1941 . .	2·80	7·3	4·4	5·8
941 . .	Five years . . .	February 1942 . .	2·80	7·9	4·9	6·6

sery trees is apt to be severed to a greater extent at the time of removal from the nursery as compared with small-sized trees, because the earth balls are generally of the same size in each case. And this fact may, in some cases, slightly upset the normal behaviour of orchard trees during the year immediately following transplanting but, in the experiments here under consideration there was no evidence of even such an influence having been introduced.

In the second and third orchard years, the trees on various rootstocks followed the same course of development and growth as in the first year except those on *kharna khatta* in the third year. It is also clear that whereas the amount of growth made by trees on rootstocks other than *kharna khatta* was increasing every year, that made by trees on *kharna khatta* retarded perceptibly. It may be mentioned in this connection that all the trees on *kharna khatta* in all the six replicates showed signs of splitting of bark below the union in 1939 and four out of 18 trees even died by the end of that year. The surviving trees dropped a large amount of foliage every winter (Plate I) and this may probably be termed as a case of delayed incompatibility.

In the fourth year, in 1941, the condition of trees on *kharna khatta* deteriorated considerably, and this is corroborated by the figure for mean annual growth increment, which works out at 60 per cent of the preceding year. It may be added that trees on all the rootstocks were bearing crop during that year, but nevertheless, those on rough lemon and smooth lemon made still greater annual increment in growth. In the fifth year, the condition of trees on *kharna khatta* deteriorated still further so much so that even trees on sweet lime (a dwarfing rootstock) had outgrown them. The data for yearly growth increment in girth, discussed above, brought out glaringly the fact that *kharna khatta* was the most unsuitable rootstock for Blood Red scion. And, in view of the performance of this rootstock with regard to the condition and vigour of Blood Red trees over a period of six years, it can be asserted that Blood Red scion should not be propagated on *kharna khatta*.

The above noted conclusion has a special significance as it is contrary to the established behaviour of *kharna khatta* rootstock with most other species of citrus. Even in case of *C. sinensis* Osbeck to which Blood Red also belongs, this rootstock is known to have produced trees of the highest vigour. Thus a particular rootstock may differ in its influence n only with different species but even wit different varieties belonging to one and the sam species. In other words, in determining th rootstock influence in case of citrus one shoul not be content merely with the study of suc influence with different species, but one shoul go a step further in that such an influenc should be studied for all such important com mercial varieties belonging to a species as appe to possess marked differences in morphologic development like Malta local and Malta Bloo Red varieties of *C. sinensis*, Osbeck.

(C) *The statistical treatment of the data given in Tables II and III (pertaining to both the field trials)*

In order to study in detail the data given Tables II and III a general curve up to th quadratic was fitted to the data by the meth of orthogonal polynomials, which was fina reduced to the significant constants only. T analysis of variance of the sum of squares co tributed by these regression coefficients in th curve was compiled separately for the data Tables II and III. That for Table II is giv in Table V, which pertains to Blood Red tre growing on rootstocks raised by the rooting cuttings.

From Table V it is evident that the lin regression is significant for all the treatmen but in case of *kharna khatta* even the quadra component is also significant. The equatio so obtained are given below:

Rough lemon :— $y = log\ x = +0{\cdot}3202 + 0{\cdot}2069\ t$
Kharna khatta : — $y = log\ x = +0{\cdot}1478 + 0{\cdot}3555\ t - 0{\cdot}0272\ t^2$
Sweet lime :— $y = log\ x = +0{\cdot}3098 + 0{\cdot}1785\ t$
Smooth lemon :— $y = log\ x = +0{\cdot}1799 + 0{\cdot}2034\ t$

The values (K) as given by the equations are :— Rough lemon = $+0{\cdot}2069$; *Kharna khatta* = $+0{\cdot}3$ $-0{\cdot}0543\ t$; Sweet lime = $+0{\cdot}1785$; Smooth lemo $+0{\cdot}2034$

The above values show that K and consequen b or the relative rate of growth of the tr remains constant on three rootstocks nam rough lemon, sweet lime and smooth-lemon it goes on decreasing in case of *kharna kha* The values for A and b, characteristic of exponential equation are given in Table VI.

The values for A show that one year a budding, the vigour of Blood Red nursery tr was comparatively far better on *kharna kh* rootstock than on others; it was about the sa on rough lemon and sweet lime, but was least of all on smooth lemon. The explana for this lies in the fact that, during the sa interval in the nursery, rootstock seedlings

Blood Red trees on *kharna khatta*
Note defoliation in all the three trees in the row

TABLE V

Analysis of variance of the sum of squares due to regression coefficients

	D. F.	Rough lemon		*Kharna khatta*		Sweet lime		Smooth lemon	
		S. S.	M. S.	S. S.	M. S.	S. S.	M. S.	S. S.	M. S.
ıear . .	1	0·74948	0·74948‡	0·47883	0·47883‡	0·55775	0·55775‡	0·72372	0·72372‡
ıadratic .	1	0·00899	0·00899	0·02752	0·02752†	0·00487	0·00487	0·00162	0·00162
ɔsidual .	3	0·00379	0·00126	0·00388	0·00129	0·00338	0·00113	0·00216	0·00072
Total .	5	0·76226	..	0·51023	..	0·56600	..	0·72750	..

† Significant at 5 per cent

‡ Significant at 1 per cent

TABLE VI

	A	b*
ɔugh lemon . .	2·090	0·4765±0·0311
ıarna khatta . .	2·519	0·3809±0·0486
ɾeet lime . .	2·041	0·4111±0·0249
ıooth lemon . .	1·513	0·4682±0·0169

* The value of *b* is obtained from the average value *k* for all the years to facilitate comparison

ıarna khatta attained the greatest height and gour whereas those of smooth lemon remained ıe weakest of all. In view of this, the initial lvantage of vigour characteristic of different ɔecies of rootstocks was reflected in the early ɾars of budded trees. But, as the vigour of ı unworked rootstock is no criterion of its gour as a rootstock when grafted or budded ith a scion variety, the response of the scion ıriety to growth and development would ulti- ately depend upon the degree of compatibility ɛtween the two symboints.

The values for *b* or the relative rate of growth, ı the other hand, show that Blood Red trees on rough lemon and smooth lemon rootstocks are characterized by a much higher growth rate than corresponding trees on sweet lime and *kharna khatta*. The differences being highly significant, it can be safely asserted that rough lemon and smooth lemon rootstocks are associated with vigorous growing trees of Malta Blood Red selon, whereas trees of the same scion would remain stunted in growth if worked on sweet lime and *kharna khatta*. In fact, on *kharna khatta*, the relative growth rate is on the decrease, and as stated before some trees have even died as a result of delayed incompatibility of Blood Red scion with this rootstock. For all practical purposes, therefore, *kharna khatta* may be regarded to have proved unsuitable as a rootstock for Blood Red scion even at this early stage of the experiment.

As stated before, a general curve was also fitted to the data is Table III. The analysis of variance of the sum of squares contributed by the regression coefficients in the curve was compiled and is shown in Table VII.

TABLE VII

Analysis of variance of the sum of squares due to regression coefficients

	D. F.	Rough lemon		*Kharna khatta*		Sweet lime		Citron	
		S. S.	M. S.	S. S.	M. S.	S. S.	M. S.	S. S.	M. S.
ıear . .	1	0·5184	0·5184‡	0·4886	0·4886‡	0·4041	0·4041‡	0·2652	0·2652‡
ıadratic .	1	0·0108	0·0108‡	0·0191	0·0191†	0·0061	0·0061‡	0·0022	0·0022
ɔsidual .	2	0·00018	0·000089	0·00057	0·00028	0·000019	0·000009	0·00109	0·00055
Total .	4	0·52938	..	0·50827	..	0·410219	..	0·26849	..

The above table shows that S. S. due to ıear and quadratic regressions were significant all cases except for citron, where only the ıear component was significant. The equaɔns, so obtained, are given below:

Rough lemon :—$y = \log x = +0{\cdot}1546 + 0{\cdot}3947\ t - 0{\cdot}0278\ t^2$.

'*Kharna khatta* :— $y = \log x = -0{\cdot}0085 + 0{\cdot}4429\ t + 0{\cdot}0370\ t^2$

Sweet lime :—$y = \log x = +0{\cdot}1663 + 0{\cdot}3260\ t - 0{\cdot}0208\ t^2$

Citron :— $y = \log x = +0{\cdot}4200 + 0{\cdot}1628\ t$

The above equations indicate that the rate of growth remains constant for citron but in case of other stock treatmeı ts the rate of growth

goes on decreasing, thus the rate of change of y can be expressed as follows:

Rough lemon $\frac{dy}{dt} = + 0{\cdot}3947 - 0{\cdot}0557\,t$

Kharna khatta $\frac{dy}{dt} = + 0{\cdot}4429 - 0{\cdot}0739\,t$

Sweet lime $\frac{dy}{dt} = + 0{\cdot}3260 - 0{\cdot}0417\,t$

Citron $\frac{dy}{dt} = + 0{\cdot}1628$

The above equations show that the rate of growth of trees on *kharna khatta* rootstock decreased more rapidly than on the remaining rootstocks. In order to compare the values for rate of growth of trees growing on different rootstocks, the averages were worked out and thus the rates were 0·2277, 0·2210, 0·2010 and 0·1628 for rough lemon, *kharna khatta*, sweet lime and citron respectively. From this it is evident that the relative rate of growth was the least when citron was used as the rootstock. This rootstock, it may be noted, was used in this experiment in place of smooth lemon, used in the other discussed before.

The results of both the trials have shown that rough lemon gave outstandingly the best results for Blood Red scion as compared with others, smooth lemon coming next, and it is also likely that the former rootstock may maintain its present behaviour in later years as well. Even more significant is the fact that *kharna khatta* which proved incompatible with Blood Red scion in both the trials, should not be used in propagating this variety. Thus although the question of rough lemon as the most suitable rootstock for Blood Red remains yet to be settled finally in view of the long range nature of these experiments, the fact that *kharna khatta* and citron are unsuitable is proved even at this early stage.

Summary and conclusions

1. The influence of certain rootstocks, propagated both from seed and cuttings, on the vigour and condition of Blood Red trees was studied for a period of six years.

2. Rough lemon gave outstandingly the best results with Blood Red scion as compared with other rootstocks, smooth lemon coming next.

3. *Kharna khatta* proved incompatible with Blood Red scion and even at this early stage of these trials, it can be asserted that this rootstock should not be used for propagating this variety.

4. Citron is yet another rootstock which proved unsuitable in case of Blood Red scion.

5. A particular rootstock may profoundly differ in its influence on scion varieties belonging to one and the same species. For instance, Blood Red on *kharna khatta* had completely failed whereas Malta local on the same rootstock is doing very well indeed.

6. Based on stem-girth measurements as these conclusions are, they may be taken with some reserve, as they may have to be revised when more data on new characters are available.

Acknowledgements

The authors are indebted to the Imperial Council of Agricultural Research, India, for financing, in the Punjab, a scheme of research on citrus rootstocks and grapevine breeding. The results reported in this paper form a part of the programme in progress in that scheme. They are also grateful to Mr H. R. Stewart, Director of Agriculture, Punjab, for his interest in this work.

Thanks are due to Mr D. N. Nanda, Statistical Assistant, Cotton Research Laboratory, Lyallpur, for statistical treatment of the data reported in this paper.

References

Afzal, M. and Iyer, S. S. (1934). A statistical study of the growth of main stem in cotton. *Indian J. agric. Sci.* **4**. 147-65

Blackman, V. H. (1919). Compound interest law and plant growth. *Ann. Bot.* **33**, 353

Fisher, R A. (1935). *The Design of Experiments* Oliver and Boyd, London

Lal Singh and Sham Singh (1942). Citrus Rootstock Trials in the Punjab, I. The vigour of young trees of sweet orange, mandarin and grapefruit as influenced by dlifferent rootstocks. *Indian J. argic. Sci.* **12**, 381-99

PLANT QUARANTINE NOTIFICATION

Notice No. 3 of 1943

United States Department of Agriculture

The following p'ant quarantine regulations and import restrictions have been received in the Imperial Council of Agricultural Research. Those interested are advised to app'y to the Secretary, Imperial Council of Agricultural Research, New Delhi, for loan.

1. White-Fringed Beet'e (Quarantine No. 72) Revision of Quarantine and Regulations.
2. Service and Regulatory Announcements—January—March 1943.
3. Service and Regulatory Announcements—Index for 1942.

GIPD—3S—444 IC of AR—30-9-44—600.

Editorial Committee

SIR PHEROZE M. KHAREGAT, C.I.E., I.C.S., *Vice-Chairman, Imperial Council of Agricultural Research*

H. R. STEWART, C.I.E., M.Sc., F.R.C.Sc.I., D.I.C., N.D.A., I.A.S., *Agricultural Commissioner with the Government of India*

E. S. FARBROTHER, M.R.C.V.S., I.V.S., *Animal Husbandry Commissioner with the Government of India*

RAO BAHADUR B. VISWANATH, C.I.E., F.I.C., F.C.S., *Director, Imperial Agricultural Research Institute, New Delhi*

F. C. MINETT, D.Sc., M.R.C.V.S., *Director, Imperial Veterinary Research Institute, Mukteswar*

ZAL R. KOTHAVALLA, B.Ag., B.Sc., N.D.D., *Director of Dairy Research, Bangalore*

J. N. MUKHERJEE, C.B.E., D.Sc., *Ghose Professor of Chemistry, University College of Science and Technology, Calcutta*

BIRBAL SAHNI, M.A., Sc.D. (Cantab.), D.Sc. (Lond.), F.R.S., *Professor of Botany, Lucknow University*

JAMES N. WARNER, M.Sc., *Professor of Animal Husbandry and Dairying, Allahabad Agricultural Institute, Allahabad*

S. KRISHNA, C.I.E., Ph.D., D.Sc., F.I.C., *Bio-Chemist, Forest Research Institute, Dehra Dun*

S. M. SRIVASTAVA, I.C.S., *Secretary, Imperial Council of Agricultural Research*

The Editorial Committee, in its work of examining papers received for publication, is assisted in an honorary capacity by a large number of scientists working in various parts of India.

Editorial communications including books and periodicals for review should be addressed to the Secretary, Imperial Council of Agricultural Research, Publication Section, New Delhi.

Communications regarding subscription and advertisements should be addressed to the Manager of Publications, Civil Lines, Delhi.

Instructions to Authors

Articles intended for THE INDIAN JOURNAL OF AGRICULTURAL SCIENCE should be accompanied by short popular abstracts of about 300 words each.

In the case of botanical and zoological names the International Rules of Botanical Nomenclature and the International Rules of Zoological Nomenclature should be followed.

References to literature, arranged alphabetically according to authors' names, should be placed at the end of the article, the various references to each author being arranged chronologically. Each reference should contain the name of the author (with initials), the year of publication, title of the article, the abbreviated title of the publication, volume and page. In the text, the reference should be indicated by the author's name, followed by the year of publication enclosed in brackets; when the author's name occurs in the text, the year of publication only need be given in brackets. If reference is made to several articles published by one author in a single year, these should be numbered in sequence and the number quoted after year both in the text and in the collected references.

If a paper has not been seen in original it is safe to state 'Original not seen'.

Sources of information should be specifically acknowledged.

As the format of the journals has been standardized, the size adopted being crown quarto (about $7\frac{1}{8}$ in. $\times$ $9\frac{5}{8}$ in. cut), no text-figure, when printed, should exceed $4\frac{1}{2}$ in. $\times$ 5 in. Figures for plates should be so planned as to fill a crown quarto plate, the maximum space available for figures being $5\frac{3}{4}$ in. $\times$ 8 in. exclusive of that for letterpress printing.

Copies of detailed instructions can be had from the Secretary, Imperial Council of Agricultural Research, New Delhi.